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REPORT ON THE COMPREHENSIVE SURVEY OF THE WATER RESOURCES OF TH--ETC(U)

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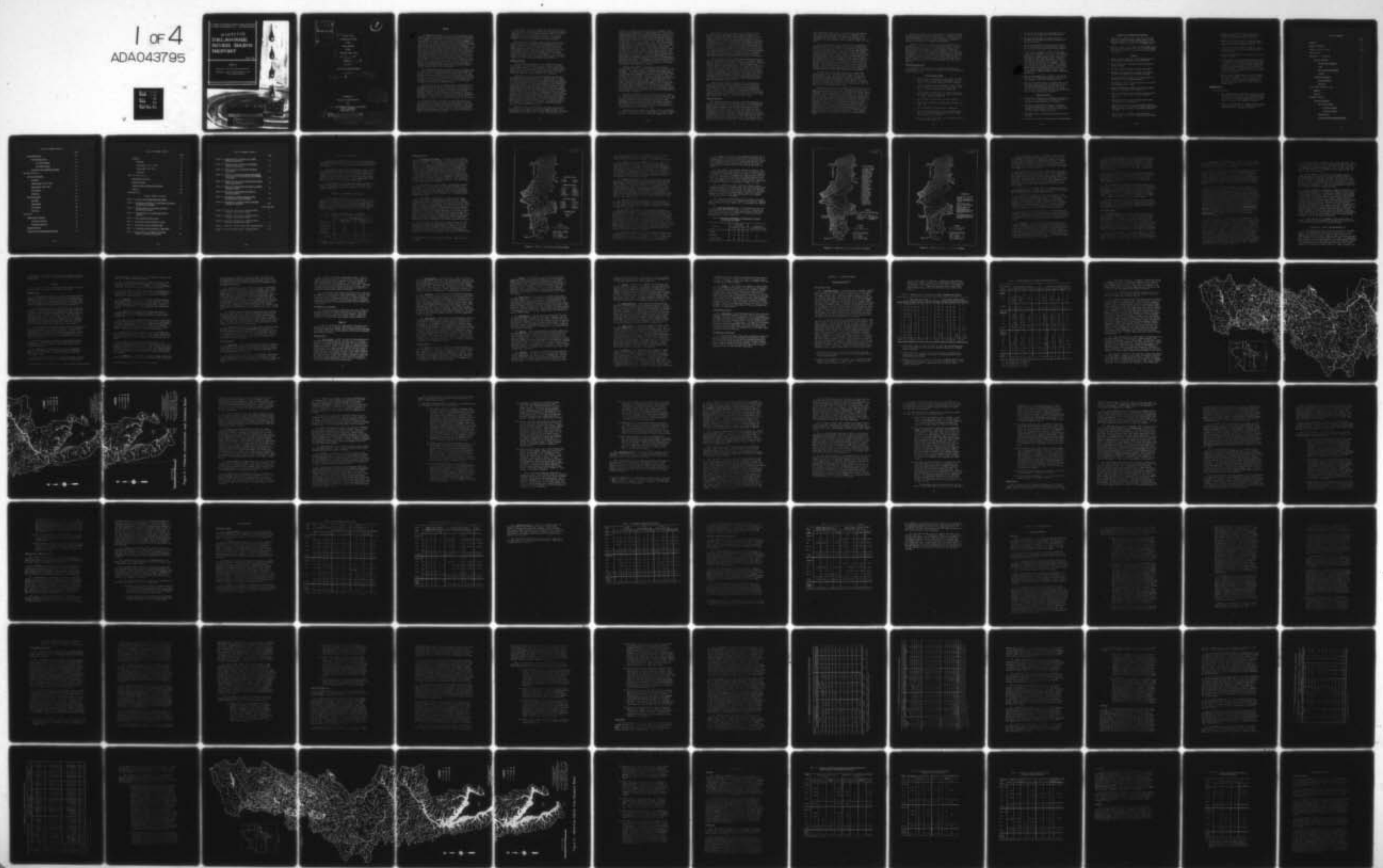

U.S. ARMY ENGINEER DISTRICT PHILADELPHIA
U.S. ARMY ENGINEER DIV. • NORTH ATLANTIC

DELAWARE RIVER BASIN REPORT

DEC. 1960

VOL. V

CONTENTS:

APPENDIX J. FISH AND WILDLIFE RESOURCES, and

APPENDIX K. USE AND MANAGEMENT OF LAND AND COVER RESOURCES.

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REPORT ON THE COMPREHENSIVE SURVEY OF THE WATER RESOURCES OF THE DELAWARE RIVER BASIN.

Volume V.

APPENDIX J and K.

FISH AND WILDLIFE RESOURCES

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PREPARED BY

FISH AND WILDLIFE SERVICE

FOR

U. S. ARMY ENGINEER DISTRICT, PHILADELPHIA
CORPS OF ENGINEERS
PHILADELPHIA, PA.

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See also Volume 6, AD-A043 796.

SYNOPSIS

The Philadelphia District, U. S. Corps of Engineers is preparing a report to recommend a comprehensive plan for development of the Delaware River Basin, with primary emphasis on water and water-related resources. This is a fish and wildlife appendix to that report. It presents reconnaissance-type data regarding the more important fish and wildlife resources of the basin, including related needs and problems, and also describes the probable effects that proposed water development projects will have on various fish and wildlife resources. This appendix also includes a plan suggesting general means whereby fish and wildlife resources can be protected and improved for the enjoyment of present and future human populations of the basin and vicinity. The information presented herein is not of the scope necessary to fulfill the obligations of the Fish and Wildlife Service under the "Fish and Wildlife Coordination Act, 48 Stat. 401, as amended; 16 U.S.C. 661 et. seq.", where water development may be by, or under the license of, Federal agencies. Where such Federal development is proposed or authorized, studies and reports of a more specific nature than this appendix will be required.

The Delaware River Basin encompasses some 12,757 square miles of land in New York, Pennsylvania, New Jersey, and Delaware plus 600 square miles of estuarine water in Delaware Bay, which lies between the latter two States in the southern third of the basin. The basin is some 270 miles long, from the headwaters in the north to the mouth of the bay in the south, and has an average width of 60 miles. The basin is divisible into three sections having generally similar physical characteristics.

The northern third of the drainage area, the Upland Section, is a rugged, highland area and includes parts of the Catskill Mountains of New York, the Pocono Mountains of Pennsylvania, and Kittatinny Mountain in New Jersey. This section is mainly forested, subject to cool summers and cold winters, and lightly populated so far as permanent residents are concerned. Recreation, by residents of other sections of the basin and of the New York City area, constitutes one of the prime human uses of this section.

The central third of the basin, the Piedmont Section, is characterized by rolling hills and irregular ridges in northern portions and by undulating terrain and broad valleys in the south. Over half the area is open land, used principally in diversified agricultural pursuits. About 10 percent of the section, principally along the Delaware, Schuylkill, and Lehigh River valleys, is heavily urbanized and industrialized.

The southern third of the basin, the Coastal Plain Section, is low and flat. It includes Delaware Bay, with broad bordering tidal marshes, and sandy farmlands used principally to produce vegetables. The main river valley portion of this section, between Trenton, New Jersey and the vicinity of Wilmington, Delaware, is highly industrialized and densely populated.

The major water development aspect proposed in the Corps' comprehensive report is a Major Water Impounding Plan (M.W.I. Plan). This plan includes a total of 19 separate reservoir projects, each of which is to be constructed on one of the larger streams of the basin. Most of the individual units are for multiple purposes. Primary multiple purposes include: water supply (including low flow regulation), flood control, hydroelectric power production, and recreation. In 8 of the 19 projects, recreation is the primary, initial purpose, and water supply, a potential additional purpose after 2010 A.D.

FISHERY RESOURCES

Important fishery resources of the Delaware River Basin include both cold-and warm-water groups of fishes in the fresh water streams and ponds of the interior sections, marine finfish and shellfish in Delaware Bay and vicinity, and anadromous and catadromous species of fish which make use of both the tidal waters and major fresh water streams of the drainage.

Cold-water fishes, trout, are most abundant and popular in the Upland Section, particularly in the streams and to a somewhat lesser extent in lakes and ponds. Heavy demands by anglers for trout fishing opportunities, complicated by the unavailability to the general public of many waters supporting trout (resulting either from closure by special interest groups or physical inaccessability), has created some rather serious problems. Supplemental stocking with hatchery-reared trout is often necessary on stream reaches which are open to the public, and even this management aid falls short of stemming overutilization of some stream reaches. Trout are also popular in the Piedmont Section but satisfactory habitat is more limited than is the case in the Upland Section. Artificial stocking, to meet public demands, is necessary on almost all stream segments of this section that support any significant amount of trout fishing. Ponds and lakes are in short supply in the Piedmont. Very little cold-water fishery exists in the Coastal Plain Section.

Warm-water fishes occur in many of the lakes and reservoirs and in some of the larger streams of the Upland Section. The more popular species are smallmouth bass, largemouth bass, pickerel, walleye, and various pan fishes. Although this group is not so

popular in the Upland Section as are trout, warm-water fishes support a significant amount of recreational use. Primary warm-water fishery problems in the Upland are associated with loss of stream habitat areas, either through inundation resulting from reservoir construction or through adverse temperature changes in stream waters downstream from deep reservoirs having low-level release works. Most of the streams, ponds, lakes and reservoirs of the Piedmont and Coastal Plain Sections of the basin present suitable habitat for warm-water fish species. Available fisheries are heavily utilized by the angling public and in many instances demand exceeds supply. Most serious problems in these sections are: physical shortage of lake areas; closure to public use of a high percentage of the lakes and reservoirs that exist; lack of public access to stream fisheries that are otherwise available and capable of supporting greater angling use, particularly the Delaware River; and reduction of stream habitat quality as the result of contamination by sediment and industrial and/or municipal wastes. An additional problem in portions of the Piedmont Section results from the introduction of acid-mine drainage and coal washings into streams.

Delaware Bay supports or influences a marine fishery resource that is one of the most productive of the North American Continent. The fisheries are of commercial and recreational importance. Commercial operations resulted in combined landings for New Jersey and Delaware of 890 million pounds in 1956. Recreational use of the bay and vicinity is estimated at 900,000 man-days of fishing annually. Principal problems associated with the marine fishery resource include: detrimental effects of storms, sedimentation, dredging and filling operations, industrial, municipal, and agricultural expansion, use of pesticides, and various types of pollution; lack of data both concerning ecological conditions and also the effects of current and potential human demands on the resources; and lack of adequate facilities to permit optimum recreational use of resources available in some sections of the bay.

Important anadromous fishes of the basin are shad, herring, and striped bass. The single catadromous species is the eel. Runs into the Delaware River and tributaries by all these fishes have displayed a downward trend during the past several decades, principally due to the pollution block that exists in the main stem river between Torresdale and Marcus Hook, Pennsylvania. Within the past two or three years, however, shad, herring, and striped bass runs have increased in size.

Construction and operation, as planned, of the 19 reservoirs in the M.W.I. Plan will have a notable impact upon basin fishery resources. Both detrimental and beneficial changes will occur.

Gross effects of M.W.I. projects upon cold-water fishery resources will be improvement of lake-type fisheries at the expense of popular and higher quality stream fisheries. Total effect of Phase I projects on trout stream resources will be destruction of 144.9 miles and unfavorable alteration of at least an additional 33.2 miles. Similar effects from Phase II projects will be destruction of 120.3 miles and unfavorable alteration of a minimum of 41.5 miles. Lake-type fisheries habitat created by Phase I, which will be suitable for the support of trout in conjunction with warm-water fishes, will total 17,720 surface acres. Some 9,170 surface acres of pools resulting from Phase II projects will provide similar habitat. The Pequest project of Phase II will destroy an important trout rearing station, including a particularly valuable natural spring water source, in New Jersey.

M.W.I. projects will affect warm-water fishery resources in much the same manner as they will change trout fisheries. Phase I projects will destroy 126.1 miles of stream fishery and unfavorably alter at least 21.7 miles additional. Phase II destruction of streams supporting warm-water fishes will total 205.5 miles, while 60 miles will be unfavorably altered. Warm-water lake fishery benefits from Phase I reservoir construction will include a total of 22,340 surface acres, 17,720 acres of which will be suitable for both cold-and warm-water fishes and 4,620 acres which will be primarily warm-water habitat. Similar incidental benefits from Phase II projects will be 19,790 total surface acres including 9,170 acres of mixed habitat and 10,620 acres specifically suitable for warm-water species of fish.

Anadromous and catadromous fisheries of the basin may be benefited in part by the M.W.I. Plan if included low-flow regulation aspects result in reduced pollution in the lower main stem. Each of the dams threaten destruction of the migratory fishes, however, through physical and temperature barriers that they will impose. Water quality improvement will be of small consequence if barrier effects threatened by each of the M.W.I. dams, particularly Tocks Island on the main stream, obtain.

WILDLIFE RESOURCES

The Delaware River Basin supports significant populations of several wildlife species or groups which are of high recreational and/or economic significance. The Upland Section of the basin is particularly important as habitat and hunting area for white-tailed deer and smaller forms of forest game. High numbers of pheasants, cottontail rabbits, and deer are supported in much of the Piedmont Section, and extremely heavy sportsman use of these game resources occurs. Although the Coastal Plain Section provides a lesser amount of high quality upland game land than does the Piedmont, it supports a significant amount of recreational use by basin residents. The broad marshes of the Coastal Plain Section

are of particular wildlife value. They present a habitat area which is of major importance to millions of migratory birds including ducks, geese, and rails and a wide variety of other marsh and shore bird species. They also provide habitat for muskrats, which have important economic values to many local residents.

Problems associated with the protection and enhancement of wildlife resources of the Upland Section are most notable with respect to deer, but also reflect on the habitat and hunting use of other forest-game species. The total hunting area available to the public is decreasing in size due to recent and current closures of large blocks of land. These closures result in inadequate deer harvest that eventually leads to overpopulations of deer and habitat destruction through over-browsing. The same circumstance results from unfavorable logging practices and natural vegetative succession in other areas. Low quality habitat has been brought about in some places as a result of these conditions. This situation has led to drastic reductions in populations of forest-game animals in such areas, with commensurate reduction in public hunting opportunity. Without correction, the problem promises to become more widespread in future years.

The main elements which are inimical to the upland game resource potential of the Piedmont and Coastal Sections are: posting against public hunting on major segments of land which are productive as farm game habitat and lack of adequate food and cover on certain other segments of the Sections. The high incidence of posting has caused some severe cases of overutilization of those areas that are open to the hunting public, which in turn has led to additional land closure.

Problems associated with the waterfowl resource extend throughout the three sections of the basin. Natural conditions in the Upland and Piedmont Sections restrict the amount of wetland habitat available. Hunting opportunity is restricted on the limited number of wetlands that are available in the northern two-thirds of the basin as a result of lack of access and of posting. Habitat problems in the primary waterfowl area, the Coastal Plain Section, stem from various marsh-destructive practices of man which include: filling--for purpose of spoil disposal from navigation works, for industrial construction, for residential and other community development, and for refuse disposal; drainage and/or diking for mosquito control and agricultural cropping; application of insecticides; and pollution. Public hunting and bird watching enjoyment of the resource is restricted in portions of the Coastal Plain by posting of, and/or lack of access to, existing wetland areas.

The M.W.I. projects will be destructive of wildlife resources through inundation and permanent destruction of important habitat and hunting areas for various wildlife species. The projects will result in additional losses in cases where periodic inundation during flood storage will decrease habitat quality.

Outright losses of deer habitat will include 30,735 acres of land (Phase I = 15,760 acres, Phase II = 14,975 acres), while unfavorable alteration will occur on 4,180 acres (Phase I = 3,350 acres, Phase II = 830 acres). Some 34,245 acres of farm game habitat will be lost permanently due to inundation by M.W.I. projects (Phase I = 14,110 acres, Phase II = 20,135 acres). Farm game resource values will be decreased on an additional 7,010 acres due to periodic inundation (Phase I = 3,170 acres, Phase II = 3,840 acres). Effects on waterfowl habitat will include total destruction of 4,118 acres, some 3,650 acres by Phase I and 468 acres by Phase II.

FISH AND WILDLIFE PLAN

Fish and wildlife resources of the basin can be protected and/or improved for the enjoyment of present and future generations in the following ways.

Fresh-Water Fisheries

a. Provide public fishing rights, and improve fish habitat and public use facilities where needed, on segments of trout streams having potentials, therefor.

b. Develop fisherman access facilities to permit optimum use of fishable fresh-water streams and lakes of the basin which are otherwise open to public use.

c. Acquire public fishing rights on closed ponds, lakes, and reservoirs which support, or could be developed to support, desirable fisheries.

d. Build headwater impoundments for public fishing.

e. Build large impoundments as warm-water fisheries for public use.

f. Open park waters to maximum public fishing use.

g. Install stream improvement devices on Paulins Kill in New Jersey to counter detrimental effects of Small Watershed project on fishery.

h. Protect upstream basin waters from detrimental effects of coal mining operations.

i. Protect all basin waters from detrimental effects of domestic, municipal, and industrial sewage.

j. Encourage maximum public fishing use at M.W.I. project pools through provision of adequate access and use facilities.

k. Provide water releases below each M.W.I. project dam within proper volume and temperature requirements to protect and/or enhance fishery resources.

l. Offset public use aspects of part of the stream fishery losses inherent in the M.W.I. Plan through acquisition of public fishing rights on a total of 121 miles of stream segments in the vicinities of the areas of loss, with development of public access and use facilities where necessary. This would include 46.2 miles for mitigation of losses from Phase I projects, and 74.8 miles as replacement for Phase II projects damages. Offset other stream losses, all associated with Phase I of the M.W.I. Plan, through provision of eight 5-acre access sites on nearby streams, without stream-mile acquisition.

m. Provide Pennsylvania Fish Commission with 100,000 rainbow trout fingerlings annually to offset natural spawning losses at the Sterling project.

n. Build a fish hatchery below the Pequest Dam for the New Jersey Division of Fish and Game and provide a firm daily water supply from the project of $3\frac{1}{2}$ million gallons at temperature 52° F. as replacement for the existing State hatchery and water supply that will be destroyed by the project.

Marine Fisheries

a. Formulate and implement a coordinated comprehensive survey of the commercial and recreational uses of the marine fishery resources of the basin.

b. Formulate and implement a complete coordinated estuarine research program relative to finfish and shellfish having present or potential values for commercial and/or recreational uses.

c. Develop new public boat-launching areas along Delaware Bay.

d. Acquire public shore-fishing areas along Delaware Bay.

Anadromous and Catadromous Fisheries

a. Construct and operate outlet works at Tocks Island project to provide seasonal releases below the dam that are favorable in volume and temperature for the welfare of fishery resources of the Delaware River.

b. Develop, construct, and operate a fish passage device at Tocks Island Dam which will help offset the physical barrier effects that the dam will have on migratory fishes.

Wildlife

a. Obtain the legislation and public backing needed to allow realistic management of deer resources.

b. Open a major part of privately-owned deer range to public hunting.

c. Increase carrying capacity of basin deer range.

d. Maintain deer populations in balance with habitat conditions through harvest by public hunting.

e. Prevent permanent destruction of wildlife habitat resulting from strip-mine operations.

f. Re-establish optimum turkey populations in all suitable habitat zones of basin.

g. Improve habitat and increase public hunting opportunities on privately-owned farmlands.

h. Improve upland-game habitat on lands owned by State and on those controlled by private sportsmen's groups.

i. Acquire and develop public hunting grounds where opportunity and need prevails.

j. Expand small marsh and pond development programs in Upland and Piedmont Sections and preserve and develop those few large wetlands in non-coastal portions of the basin.

k. Improve habitat conditions on waterfowl areas in Coastal Plain Section where vulnerability to destruction is low.

l. Improve public waterfowl hunting opportunity on estuarine marshes by providing needed access facilities on areas not closed by posting.

m. Develop and implement feasible measures whereby spoil disposal from navigation works will improve, replace, and/or create waterfowl habitat.

n. Develop and implement insect control and waterfowl development methods that are mutually acceptable to both interests.

o. Develop waterfowl habitat in conjunction with road building endeavors.

p. Offset wildlife losses resulting from M.W.I. project inundation by acquiring and developing a total of 71,860 acres of land, in segments, in vicinities of areas of loss, to replace wildlife habitat and public hunting opportunities. Some 31,400 acres will be required to mitigate Phase I effects while mitigation needs for Phase II destruction include a total of 40,460 acres.

q. Provide the New Jersey Division of Fish and Game with a 260 acre parcel of bottom land in northern New Jersey, complete with buildings and other improvements and facilities, as replacement for existing State game lands to be lost to the Tocks Island project.

RECOMMENDATIONS

It is recommended:

1. That preservation and enhancement of fish and wildlife resources, and provision for reasonable public use thereof, be a purpose of any water-use development project in the basin regardless of who shall finance, construct, and operate the project.

2. That the outlined Fish and Wildlife Plan be adopted as an integral part of the comprehensive plan for development of the Delaware River Basin.

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SECTION I. INTRODUCTION

1. This report discusses the fish and wildlife resources of the Delaware River Basin, and treats the effects of a water development plan thereon. Both general and project-related criteria are included.

2. The plan considered herein is designed to make the best use of Delaware River Basin surface waters during the next 50 to 100 years through the construction of 19 dams on various main streams of the basin. Most of the dams would be built in the central third of the basin, north of Philadelphia, Pennsylvania and south of Port Jervis, New York. A major percentage of the reservoirs would be of the multiple-purpose type.

3. The primary aim of this Main Water Impounding Plan is to improve water supply (including low flow regulation), flood control, hydroelectric power, and recreation conditions in the Delaware River Basin.

SECTION II. DESCRIPTION OF THE BASIN

4. The Delaware River Basin comprises all or part of 38 counties in four States; these include 5 in New York, 17 in Pennsylvania, 13 in New Jersey, and 3 in Delaware, as indicated in figure 1. It is some 270 miles in length and averages about 60 miles in width, the width varying from 40 to 90 miles. The distribution of the 12,757 square-mile basin among the 4 States is given in table 1.

Table 1.--Area of the Delaware Basin by States 1/

	Drainage Area	
	Square Miles	Percent
New York	2,362	19
Pennsylvania	6,422	50
New Jersey	2,969	23
Delaware	1,004	8
TOTAL	12,757	100

1/ A small portion of Maryland, 8 square miles, is not considered either in this table or report.

Physical Features

5. Geology and Topography. -- Actually, five physiographic provinces, represented by portions of 8 subdivisions or sections, occur in the basin. These component sections and provinces, from north to south, are: (1) The Catskill Mountains and Glaciated Sections of the Appalachian Plateau Province; (2) the Middle Section of the Ridge and Valley Province; (3) the Reading Prong Section of the New England Province; (4) the Northern Piedmont Lowland, Piedmont Upland, and Lancaster-Frederick Lowland Sections of the Piedmont Plateau Province; (5) the Embayed Section of the Coastal Plain Province. For convenience in presentation of the material in this report, the Delaware River Basin has been divided into three parts, instead of adhering to the 5 province zoning system. These are the Upland, Piedmont, and Coastal Plain Sections and are shown in figure 1.

6. The Upland Section is a rugged, highland area dominated principally by 2 land masses, the Catskill Mountains to the northeast in New York and the Pocono Mountains to the southeast in Pennsylvania. Kittatinny Mountain in New Jersey, immediately east of and parallel to the Delaware River, is a third and lesser prominence, a high-ridge which culminates at its southern end in Delaware Water Gap.

7. The Catskill Mountains are the largest of the 3 land masses, with elevations averaging about 2,000 feet.[2/] A number of peaks range between 3,000 and 4,204 feet, the latter elevation being the summit of Slide Mountain, the highest point in the basin. Ridges on the Pocono Mountains vary from 1,100 to 2,130 feet, the summit of Camelback Mountain. Kittatinny Mountain has a maximum elevation of slightly over 1,000 feet. Most of the section has been glaciated, from the highest elevations down through the generally narrow, steep-sided valleys which are filled with deep deposits of glacial debris. The remainder of the Upland part of the basin is composed of series of fairly high parallel ridges separated by the narrow valleys mentioned above. Both ridges and valleys are oriented generally in a northeast-southwest direction.

8. The northern two-thirds of the Piedmont Section is characterized by rolling hills and irregular ridges, lower and less prominent as highland topography than the terrain to the north. The southern limit of glaciation in the basin reached this part of the section (figure 1). The lower third of the Piedmont is undulating terrain, comprised mostly of low hills and broad valleys.

2/ All elevations in this report are referred to mean sea level datum.

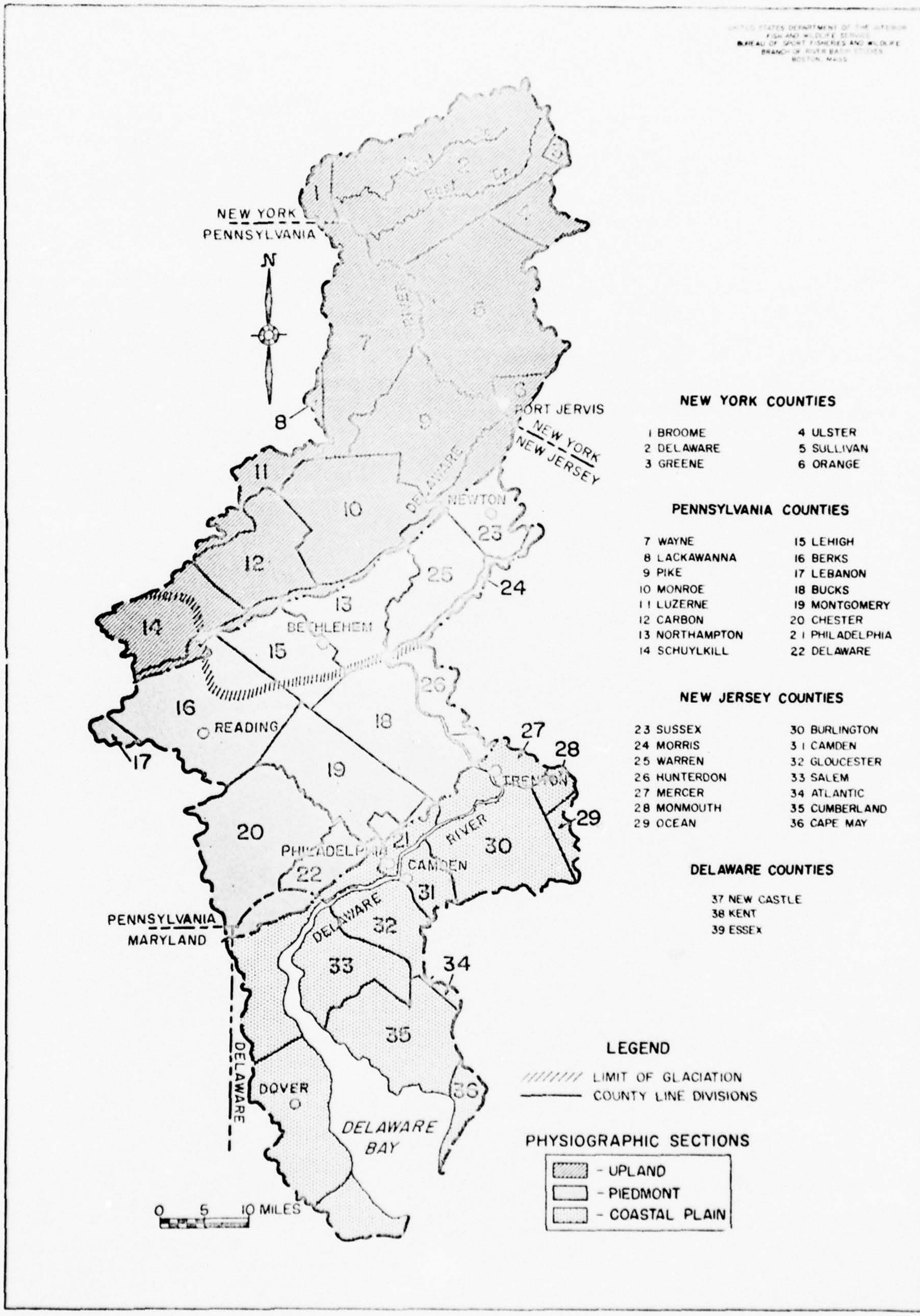


Figure I. – Political subdivisions Delaware Basin

9. The fall line marks the boundary between the Piedmont and Coastal Plain Sections. This plain is flat and low, in marked contrast to the other 2 parts of the Delaware River Basin.

10. The main stem of the Delaware River is, of course, the principal stream of the basin. Its source is located near Stamford, New York and its mouth has been established arbitrarily opposite Liston Point, Delaware, in the absence of a distinguishable geologic demarcation between the termination of the river and the beginning of Delaware Bay into which it empties. From its mouth to Trenton, New Jersey, the river is subject to tidal action. Its non-tidal portion between Trenton and Stamford, New York is approximately 280 river-miles in length.

11. Delaware Bay consists of that broad portion of the Delaware River Estuary upstream from the bay entrance at Cape May and Cape Henlopen. This tidal bay, approximately 600 square miles in area, is about 45 miles long and from 4 to 30 miles in width and receives the fresh water flow not only of the Delaware River and its tributaries but also of several streams south of Liston Point in New Jersey and Delaware. The Delaware River Estuary may be delimited - from a biological though not from a physiographic standpoint - as the coastal tidal body of water, including the bay and a portion of the Atlantic Ocean, in which measurable dilution of sea water by fresh water occurs.

12. The salinity of the bay varies with location, river flow and daily mean river level, and tidal action with its attendant mixing of ocean and fresh water. Generally, the salinity decreases in concentration northward from the mouth of the bay to the limit of tidal flow near Trenton.

13. The names and locations of the principal tributaries of the Delaware River within the three sections and four States of the basin are shown in figure 2. Natural and artificial lakes and ponds are abundant in the basin although their distribution is not uniform among the three sections. Most of them are situated in the Upland; the Piedmont and Coastal Plain Sections rank a poor second and third, respectively, in this category. These lakes and ponds vary in size from less than 10 acres to more than 6,000 acres. The largest, a water supply reservoir for the City of New York, is Pepacton Reservoir on the East Branch Delaware River. It is one of several large impoundments in the Upland Section of New York and Pennsylvania constructed as sources of municipal water and hydropower.

14. Other descriptive material on the streams, lakes, and ponds of the basin and discussions of the relation of many of them to the fish and wildlife resources of the basin will be held in abeyance at this point, since these data are presented in succeeding pages of this report and within included and appended figures and tables.

15. Soils. -- The soils of the Delaware River Basin can be classified into 10 groups as determined by their physical and chemical properties, derivation from parent material, and texture. The generalized characteristics of these groups and their location in relation to the three physical sections and to the glaciated and unglaciated zones of the basin are presented in figure 3.

16. The upland soils originate largely from glacial till, outwash material, and crystalline rock. Most of them are poorly or imperfectly drained and have low infiltration rates, except on the steep slopes where well drained but shallower soils are more common. A small area of generally well drained glaciated limestone soils (Group 2) occurs in the southwestern part of the section. The Upland section is located within the zone of glaciation and nearly all areas of it are gravelly, flaggy, or stony.

17. In the Piedmont, soils which are moderately deep to shallow and have low infiltration rates have been developed mostly on shale and sandstone. The deep ones with higher infiltration rates have developed on schist, gneiss, and quartzite. The upper third of the section has been glaciated. Heavy soil textures varying from loams to clay loams predominate in the Piedmont Section, as is true of the Upland.

18. Soils of the Coastal Plain Section within a zone adjacent to the Piedmont Section are generally well drained. Eastward and southward they become sandy, well to exceedingly well drained, and dry.

19. Cover types and Land use. -- In generalized terms, the cover type-land use situation within the basin is summarized by sections, with respect to the percentage of area in rural lands, both forested and open, and in urban or industrialized lands, approximately as shown in table 2.

Table 2.--Estimated percentage of total area of sections in various cover types

Section	Rural Land		Urban and Industrialized Land
	Forested	Open	
Upland	75	20	5
Piedmont	30	60	10
Coastal Plain	20	65	15

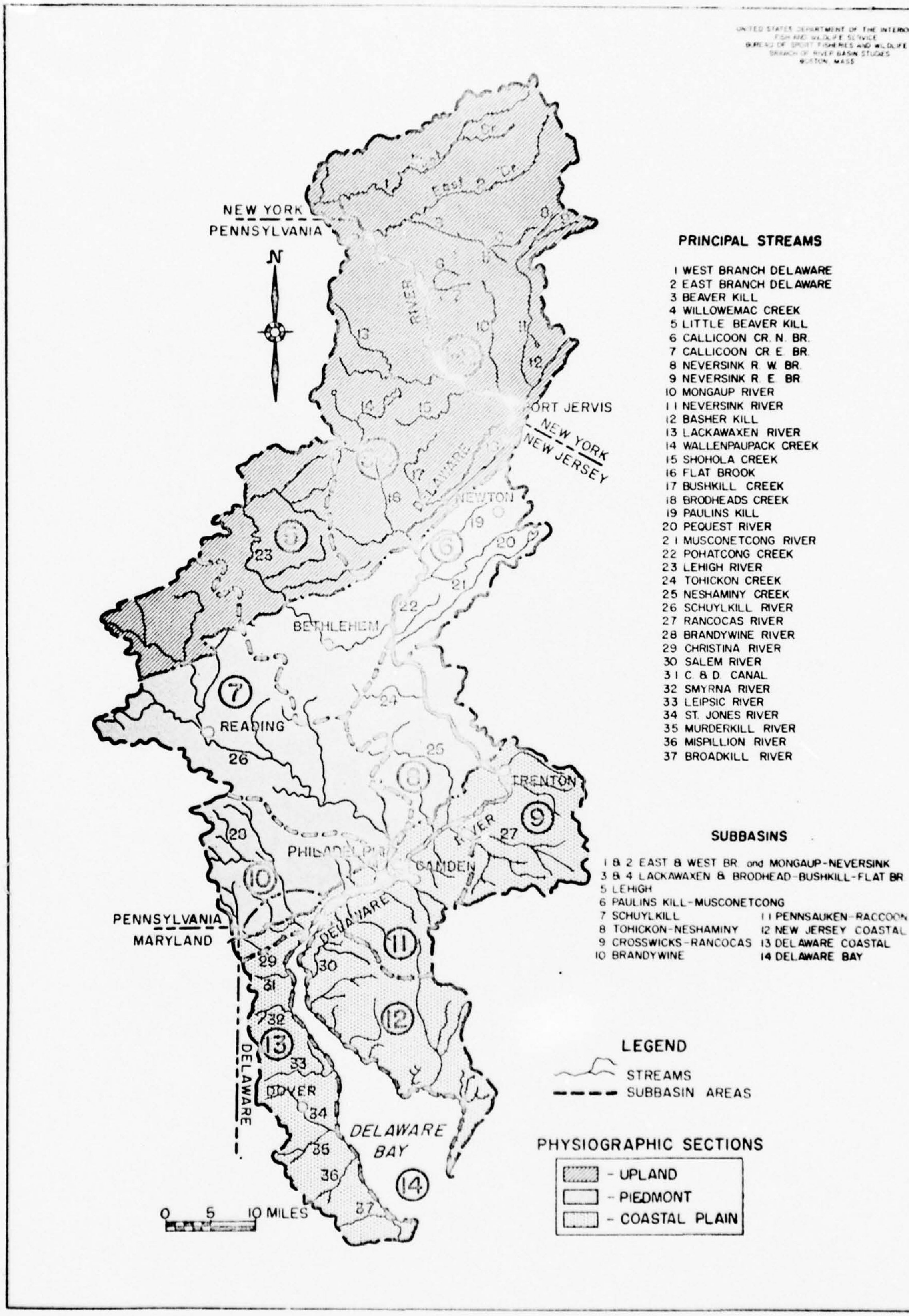


Figure 2. — Watershed subdivisions Delaware Basin

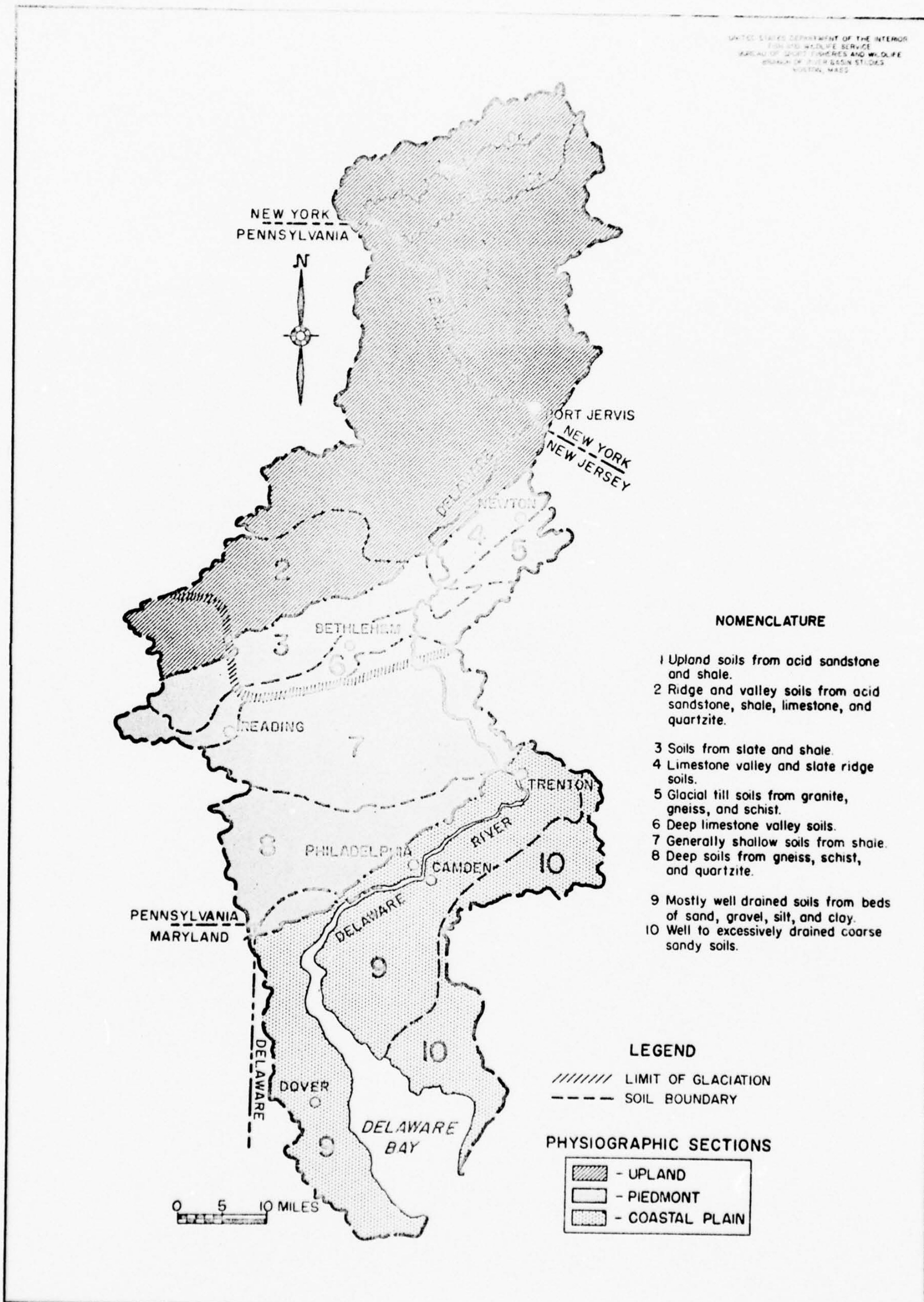


Figure 3. – Soil type subdivisions Delaware Basin

20. An estimated 80 percent of the basin woodland consists of non-farm woods, and the remainder, farm woodlots. Most of this woodland is comprised of understocked stands in young age classes. Older stands are also generally understocked. Grazing of woodlands in the basin is confined mostly to farm wood lots, some 20 percent of which are subjected to this practice which is detrimental both to timber production and protection of the watersheds against excessive water runoff.

21. Hardwood stands make up about two-thirds of the woodland area; mixtures of hardwoods and conifers, about one-quarter; and coniferous stands, the remainder. Most of the original woodland stands have been logged by clear cutting and/or burned in times past, especially during the 19th and early part of the 20th centuries. In more recent times, better forest management procedures, in the form of improved cutting practices and fire suppression and control have been instituted in many wood lot and forest tracts.

22. Most of the open rural lands of the basin are used for agricultural purposes. Crop and livestock production and dairying are the principal forms of agricultural land use.

23. Dairying is probably the chief farm industry in the Upland Section. Considerable abandonment of farmland has occurred in this section during the past few decades. Agricultural production in the Piedmont is fairly diversified and consists largely of the three types mentioned previously. In the Coastal Plain Section, vegetable raising is the chief farming activity. Where soils are not favorable for vegetables, grain crops and livestock are produced. Poultry raising is also important.

24. Little need be said at this point concerning urban and industrial land use within the basin except to mention the rapid invasion of rural areas by both residential and industrial developments, especially since the beginning of World War II. This trend has been most pronounced in the Coastal Plain and Piedmont Sections.

25. Climate. -- Cool summers and winters associated with mountainous portions of the northeastern United States are also common in the Upland Section of the basin. In the Piedmont, the climate assumes a character having elements of both adjoining sections. In both Piedmont and Upland Sections elevation plays a significant role in influencing climate. Since the Coastal Plain is closely associated geographically with 2 large bodies of water, Delaware Bay and the Atlantic Ocean, its climate is greatly moderated by the influence of these waters.

26. Rainfall throughout the Delaware River Basin varies little from an average annual figure of approximately 44 inches, except at the higher elevations where it approaches 60 inches per year. In an average year, seasonal rainfall shows only small variation from the average monthly total. Droughts and periods of excessive rain are by no means unknown, however. Flood producing storms, sometimes of hurricane intensity, are experienced at times.

27. In the Upland Section, average annual snowfall ranges between 30 and 60 inches; in the northern Piedmont, between 35 and 40 inches; and in the southern Piedmont, 20 - 25 inches. The amount which falls differs locally within each section. Only slight precipitation in the form of snow falls in the Coastal Plain Section.

28. Average summer temperatures range approximately from 60° to 68° F. in the Upland; from 66° to 75° F. in the Piedmont; and from 68° to 77° F. in the Coastal Plain portion of the basin. Average winter temperatures range from about 13° to 30° F. in the Upland; 30° to 35° F. in the Piedmont; and 34° to 40° F. in the Coastal Plain Section. Elevation and distance from large bodies of water are important factors in determining the magnitude of average summer and winter temperature ranges.

29. Growing seasons differ in length at various locations, depending also on elevation and local climatic conditions. In the northern portion of the area growing seasons roughly approximate 120 days, and in the Piedmont and Coastal Plain Sections they average between 185 and 190 days.

Commercial Features

30. Human Population. -- Nearly 6 million people live in the Delaware River Basin. Probably 95 percent of these inhabitants reside in the Piedmont and Coastal Plain Sections and a large percentage of these are concentrated in a 10 mile wide zone along both sides of the Delaware River. The zone along the western side of the river contains much the heavier population of the two. The proportion of urban to rural residents is low in the Upland and considerably higher in the Piedmont and Coastal Plain Sections where the larger metropolitan areas, Philadelphia, Trenton, Allentown-Bethlehem-Easton, and Wilmington are located.

31. The basin population is increasing rapidly. According to some estimates it is rising at the rate of approximately 2 percent each year. At this rate of increase, the total population will be more than 138 percent larger in 2010 A.D. than it was in 1950.

32. Industry. -- The Delaware River Basin is one of the most highly industrialized areas of the United States. Within its borders are located nearly every type of commodity and non-commodity producing industry represented in the Nation.

33. These enterprises are not uniformly distributed within the basin. Most are located in the Piedmont and Coastal Plain Sections in and near urban areas. The most important industrial centers are the metropolitan areas of Allentown-Bethlehem-Easton, Reading, Philadelphia, Trenton, and Wilmington on the Delaware River and its 2 principal tributaries, the Lehigh and Schuylkill Rivers. Smaller communities in these sections of Pennsylvania, New Jersey, and Delaware also contribute to industrial production on a smaller scale.

34. The list of activities and products associated with the industrial economy is long and too repetitious if presented by location. Some of the important ones connected with one or more of the metropolitan areas mentioned previously are: the manufacture of textiles, paper and paper products, wearing apparel, leather and rubber goods, electrical goods, fabricated metal products, machinery, chemical products; shipbuilding; oil refining; and the production of primary metals, chemicals, and cement. Other important industries of the basin include the following: anthracite coal mining in the upper Lehigh and Schuylkill Watersheds; logging, lumbering, and forest products, chiefly in the Upland Section; agriculture, in all sections (discussed previously under the heading Cover Types and Land Use in this report); food processing in Delaware and southwestern New Jersey; commercial fishing and fish processing in and adjacent to Delaware Bay (to be discussed under the heading Marine Fishes in the Fisheries Section of this report); and the business of recreation.

35. The business of recreation needs some elaboration here because of its association with fish and wildlife resources. These resources are indeed 2 of the wellsprings of economic benefits accruing to hundreds of thousands of people in scores of businesses associated with outdoor recreation in the basin. It is beyond the scope of this report to present a treatise on recreation as a business in this area. Suffice is to say that it is a multimillion dollar industry sustained by the money spent by millions of persons at all seasons of the year in their quest for outdoor relaxation. In addition to hunting and fishing, they swim, boat, camp, hike, ski, look at the scenery, and otherwise loaf in those localities where mountain, valley, forest, farm, lake, pond, stream, marsh, and bay provide the setting and natural facilities for these activities. Such settings and facilities are found in the Delaware River Basin. The Upland Section is especially noted for the types of land and water and associated activities mentioned.

36. The millions who partake of such outdoor recreation can reach the general locale of their sports and pastimes in all portions of the basin in a matter of hours, or at most, one day by automobile, railroad, or air transportation. Those who hunt, fish, camp, or hike find difficulty in some areas in negotiating the last few laps of their outdoor trips.

37. Those areas of the basin in which big game hunting, upland game hunting, waterfowl hunting, fresh-water fishing for cold-and warm-water fishes, and salt-water fishing are pursued as sport by hundreds of thousands of resident and non-resident sportsmen are mentioned in succeeding sections of this report, in which may also be found treatment of many of the problems and shortcomings associated with capability of these fish and wildlife resources to meet the needs of people who depend upon them.

38. One other aspect pertaining to hunting and fishing for the game mentioned above which is inferred or covered elsewhere in this report is the contribution by hunters and fishermen to the economy of the Delaware River Basin. Few reliable statistics are available to point up the economic importance of hunting and fishing in this area or in most other parts of the country. However, the money poured into the tills of persons and enterprises providing goods and services needed or desired by sportsmen in the basin amounts to millions of dollars every year. Most of this money ultimately benefits people who reside in the Delaware River Basin. Hunters and fishermen spend their recreation dollars for the following goods and services, among others: sporting arms and ammunition; fishing tackle; purchase of fishing boats and motors; rental of boats and motors; gasoline and oil for boats and motors and for transportation to and from hunting and fishing areas; outdoor clothing; camping equipment; food; and rooming accommodations.

39. These are some of the examples which indicate that the sports of hunting and fishing have also assumed a big business status in the basin as well as in the country at large.

SECTION III. MAJOR WATER IMPOUNDING PLAN

40. The basin plan for the control and utilization of surface waters of the Delaware River Basin will be executed in 2 phases. Phase I, the initial portion, provides for the construction of 5 separate dams previous to 1980. Phase II entails 16 additional dams, with construction to be initiated after 1980. Under the appropriate phase headings, the individual projects of the Major Water Impounding Plan are treated below to the extent possible with available location, engineering, and operational data. They have been further grouped by the three physiographic sections - Upland, Piedmont, and

Coastal Plain - into which the basin has been divided to facilitate presentation of the fish and wildlife resource material in this final report.

Phase I

41. The Tocks Island, Sterling, Tobyhanna, Basher Kill, and Bernville dams are included in this part of the plan.

Upland Section

42. Tocks Island. -- This will be a multiple-purpose dam and reservoir located on the Delaware River in New Jersey and Pennsylvania. The dam site is about 7 miles above the Delaware Water Gap. Water supply, low flow regulation, and flood control constitute the primary reasons for this unit; inclusion of hydropower as a project purpose is a further possibility being considered.

43. The dam will be built at elevation 300. [3/] An inactive pool will be held at elevation 334 which will inundate 1,600 acres of land including 18 miles of the Delaware River and .8 mile of Flat Brook. The storage specifically allowed for water supply and low flow regulation will be to elevation 395. This pool will inundate a total of 9,400 acres of land, including 34.3 miles of the Delaware River and 11.2 miles of Flat Brook. It is probable that, although the full pool will be held through some portion of each year, under average annual conditions there will be a pool about 30 percent smaller, some 7,060 acres in surface area.

44. Storage between elevations 395 and 420 will be reserved for flood control purposes. No data are available concerning expected flood frequency and related storage conditions. At full pool (elevation 420), the reservoir will inundate 14,000 acres of land and stream. Approximately 40 miles of the Delaware River, 12.5 miles of Flat Brook, and 2.5 miles of the Neversink River will be covered by this pool.

45. Some thought has been given to including hydroelectric power as one of the purposes at the Tocks Island Dam. The consideration has been of a tentative nature, and no data on this feature are available.

46. Sterling. -- This dam will be built on Wallenpaupack Creek at the upstream limit of Lake Wallenpaupack in Wayne and Pike Counties, Pennsylvania. Reservoir operation will be for flood control only.

47. The dam will be built at elevation 1190 and will control a drainage area of 143 square miles. A 200-acre inactive pool at

3/ All elevations in this report refer to feet above mean sea level datum.

elevation 1206 will inundate $\frac{1}{4}$ mile of Wallenpaupack Creek and one mile of West Branch Wallenpaupack Creek.

48. At full pool, elevation 1271, some 1,480 acres of land and stream will be inundated, including 3.2 miles of the main stream and over 4 miles of the West Branch. No data are available concerning the expected operational features of this unit.

49. The Corps of Engineers states that this particular unit may be deleted from the plan if detailed studies and negotiations indicate that suitable alternate flood control can be achieved through use of Lake Wallenpaupack.

50. Tobyhanna. -- This will be a multiple-purpose dam and reservoir on the Lehigh River about 15 miles southeast of Wilkes-Barre, Pennsylvania. The dam will be at the head of the pool of the Bear Creek project which is under construction. The unit is designed for water supply, low flow regulation, and hydroelectric power.

51. Valley floor elevation[4/] at the dam site is 1405. A 900-acre inactive pool is planned at elevation 1490 which will inundate over 5 miles of the Lehigh River and 3.7 miles of Tobyhanna Creek.

52. The full pool at elevation 1560 will have a surface area of 3,800 acres, covering a total of 9.5 miles of the Lehigh River, 6.5 miles of Tobyhanna Creek, .6 miles of Trout Creek, and reaches less than a mile in length on each of several other tributary streams. The pool will serve all project purposes and no designation of various pool segments is made for each purpose.

53. The total storage in the full pool, not including the inactive pool, will be 140,000 acre-feet. In current plans 85,000 acre-feet of this total are reserved for water supply and low flow regulation combined, while the remaining 55,000 acre-feet are for power.

54. There are no firm operational data for this unit. Estimates by the planning agency place the average annual pool size at about 2,930 acres, about 70 percent of the full pool, which will probably be held periodically during the year. The planning agency indicates that there will be consideration of pump-storage features at this dam toward the end that hydroelectric power potentials may be increased.

55. Basher Kill. -- This will be a pumped-storage hydroelectric power project constructed without Federal expense. The project will

4/ Terminology as given in Corps of Engineers data.

have multi-purpose features, however. Two dams, one across the Neversink River and one across the Basher Kill, and a weir across the Delaware River will be required. The principal portion of the unit will be north of Port Jervis, New York in the Neversink River and Basher Kill valleys.

56. The main dam, Cejwin, will be built across the Neversink River at valley floor elevation 412, just northeast of Port Jervis. It will be over 200 feet high and control a drainage area of 326 square miles of the Neversink and Basher Kill watersheds. The planned inactive pool at elevation 559 will have a surface area of 8,500 acres and will inundate 8.8 miles of the Neversink River, 12.6 miles of the Basher Kill, 1 mile of Pine Kill, more than 20 miles of the abandoned Delaware and Hudson Canal, and over 100 acres of Martin Lake. The full power pool, elevation 630, will present 11,300 acres of water surface and inundate additional stream reaches on the Neversink River and the Pine Kill, 2 miles and $\frac{1}{2}$ mile, respectively. The average size of the operating pool will be 10,460 acres.

57. Wurtsboro dam will serve as a major dike at the upstream end of the reservoir pool, to allow the holding of water levels to elevations in excess of the height of the natural divide between the Basher Kill watershed and that of Roundout Creek, a tributary to the Hudson River. This dike will be a major feature constructed across the valley about equal distance between Wurtsboro and Summitville. At valley floor elevation 535 it will permit depths at the upper end of the full pool of over 90 feet.

58. The Basher Kill weir will be built within the Tocks Island Reservoir site. It will cross the Delaware River just east of Milford, Pennsylvania. The structure will be at elevation 391 and will hold water to elevation 420 when full, inundating 7 miles of the Delaware River and 2.5 miles of the Neversink River. The weir will make possible the raising of water levels immediately below Cejwin Dam for pumping purposes.

Piedmont Section

59. Bernville. -- This is a multiple-purpose dam and reservoir unit in Berks County, Pennsylvania, the site for which is situated on Tulpehocken Creek, about 10 miles northwest of Reading, Pennsylvania. The expressed purposes for the unit are water supply, low flow regulation, and flood control.

60. The dam will be built across the Tulpehocken Creek Valley floor at elevation 280. The inactive pool at elevation 297 will have a surface area of 150 acres and will cover 4 miles of Tulpehocken Creek, 1 mile of Northkill Creek and .2 miles of Little Northkill Creek.

61. A total of $7\frac{1}{2}$ miles of Tulpehocken Creek, 3 miles of Northkill Creek, 2.7 miles of Little Northkill Creek, and 2.2 miles of Mill Creek will be inundated by the pool designed for water supply and low flow regulation. If full at elevation 347, this pool will have a surface area of 2,350 acres. Although this pool will be held at maximum for portions of most years, it is expected that average conditions throughout each year will result in a surface area of about 1,690 acres.

62. The reservoir basin between elevations 347 and 361 will be reserved for flood control under current plans. The full flood pool will cause inundation of 3,450 acres of land and water, including 10.7 miles of Tulpehocken Creek, 3.5 miles of Northkill Creek, and lesser mileages of each of several other tributaries. No data are available concerning operational features relative to flood control.

Alternatives or Additions

63. The planning agency states that there may be basis for including 5 run-of-river power projects below the Tocks Island Dam site in Phase I if minimum flows are adequate. Detailed studies have not been made on this item to date, however, and inclusion of the additional units appears highly speculative.

Phase II

64. The 16 individual units included in this phase of the project plan are the following: Hawk Mountain, Shohola Falls, Beltzville, Aquashicola, Paulina, Pequest, Hackettstown, New Hampton, Trexler, Tohickon, Newtown, Maiden, French Creek, Evansburg, Newark, and Christiana.

Upland Section

65. Hawk Mountain. -- This will be a multiple-purpose unit for water supply and recreation. The dam site is on the East Branch of the Delaware River about 8 miles above its confluence with the West Branch at Hancock, New York. An inactive pool is planned at elevation 1,008. At full capacity (elevation 1,082) the dam will form a long, winding reservoir that will extend to within 2 miles of the Pepacton Dam, will have a surface area of 5,300 acres, and will inundate 23 miles of East Branch Delaware River, 5.8 miles of the Beaver Kill and a total of 4.5 miles on the lower portions of Read, Fish, Branch, and Baxter Creeks and Trout Brook. Although the pool will be held full at various times, the average operating pool will be about 70 percent of the total, some 3,785 acres in surface area.

66. Shohola Falls. -- This dam will be located on Shohola Creek at Shohola Falls in Pike County, Pennsylvania. The unit will be for hydroelectric power only. The dam site is at elevation 1140. The designed inactive pool at elevation 1145 will have a surface area of 500 acres. The full pool, elevation 1,183, will inundate 1,520 acres, including 1,200 acres of wetland, 4.6 miles of Shohola Creek and 1 mile of Rattlesnake Creek. Operating conditions will probably result in an average pool of approximately 1,215 acres.

67. Beltzville. -- This will be a multiple-purpose dam and reservoir on Pohopoco Creek 3 miles east of Lehighton, Pennsylvania. The unit is designed for water supply, low flow regulation, and flood control. The dam site is at valley floor elevation 490. The inactive pool, at elevation 568, will have a surface area of 410 acres. The maximum operating pool, that designed for water supply and low flow regulation purposes, will have a surface area of 800 acres and the total pool to this height will inundate 5.8 miles of Pohopoco Creek and .7 miles of Pine Run. Under normal operating procedures this pool will have an average surface area of 680 acres. The full pool, which includes flood control storage, will inundate a total of 1,280 acres including 7.1 miles of Pohopoco Creek and 1 mile of Pine Run.

68. Aquashicola. -- This will be a multiple-purpose reservoir on Aquashicola Creek for water supply, low flow regulation, and flood control. The dam will cross the valley floor at elevation 420, about 1 mile upstream from the community of Palmerton East, Pennsylvania. An inactive pool at elevation 435 will flood some 110 acres of land and water. The maximum pool for water supply and low flow regulation will flood 925 acres at elevation 491. At this height the reservoir will inundate 6 miles of Aquashicola Creek, 3.5 miles of Buckwha Creek, and $\frac{1}{4}$ mile of Hunter Creek. The average surface acreage presented through operation of this pool will be 680 acres. The full reservoir, including flood control, will inundate 1,275 acres at elevation 510. Some 7.2 miles of the main stream, 5 miles of Buckwha Creek and .5 miles of Hunter Creek will be covered by the reservoir when full.

Piedmont Section

69. Paulina. -- This unit will be for water supply and low flow regulation. The dam site is at elevation 345 on the Paulins Kill, slightly over a mile east of Blairstown, New Jersey. A 200-acre inactive pool is designed at elevation 403. The full operating pool will inundate 1,650 acres of land and water, including 9.4 miles of the Paulins Kill and all of 66-acre White Lake, and will extend to the dam at Paulins Kill Lake. The average size of the operating pool will be about 1,215 acres.

70. Pequest. -- Like Paulina, this unit will be for water supply and low flow regulation. The dam will be constructed at Bridgeville, New Jersey, crossing the Pequest River at valley floor elevation 420. Storage to elevation 455 is designed as the inactive pool. This pool will have a surface area of 250 acres. The full pool will inundate 1,400 acres of land and water, including 7.1 miles of the Pequest River, 1.9 miles of Mountain Lake Brook, all of Mountain Lake (122 acres), and 280 acres of Cat Swamp. The average size of the operating pool will be about 1,055 acres.

71. Hackettstown. -- This will be a multiple-purpose unit for water supply and low flow regulation which will impound waters of the Musconetcong River. The dam site is between Hackettstown and Saxtons Falls, New Jersey at valley floor elevation 610. An inactive pool is planned at elevation 630 which will have a surface area of 180 acres. The full pool will inundate 1,200 acres of land and water. Maximum flowage will cover 6.5 miles of the Musconetcong River, 1.2 miles of Dragon Brook, 50-acre Saxton Lake, and 50 acres of the Waterloo Lakes. The normal operating pool will average 894 acres in surface area.

72. New Hampton. -- The New Hampton Reservoir will be built on the Musconetcong River about 2 miles north of Hampton, New Jersey and a mile east of Washington, New Jersey. The dam will cross the river at elevation 339. A 160-acre inactive pool is designed at elevation 373. The full pool will have a surface area of 1,560 and will cover 7 miles of the Musconetcong River, 2.4 miles of Vanatta Run, and .6 miles of Hance Run. Average size of the operating pool will be about 1,140 acres.

73. Trexler. -- This reservoir will be for water supply, low flow regulation and flood control purposes. The dam will be built across Jordan Creek at elevation 400, some 6 miles northwest of Allentown, Pennsylvania. The unit will have a 70-acre inactive pool to elevation 415. At elevation 478, the total portion of the reservoir designed for water supply and low flow regulation purposes will include 850 acres of land and water. About 5.3 miles of Jordan Creek and 2.5 miles of Lyon Creek will be included. Under normal operating conditions the average size of this pool will be 620 acres. The full reservoir, at elevation 495 including flood control, will inundate some 1,260 acres.

74. Tohickon. -- This unit is designed for water supply and low flow regulation. The dam site is on Tohickon Creek in Bucks County, Pennsylvania, some 8 miles east of Quakerstown. The dam will be constructed across the valley floor of Tohickon Creek at elevation 304. The planned inactive pool at elevation 335 will flood 100 acres. The full reservoir will cover an area of about

1,500 acres and will inundate 7 miles of Tohickon Creek, 2 miles of Haycock Creek, and 1 mile of Three Mile Run. The average size of the normal operating pool will be 1,080 acres.

75. Newtown. -- This unit is planned for water supply and low flow regulation purposes. The dam site is on Neshaminy Creek some 3 miles west of Newtown, Pennsylvania. The dam will be constructed across Neshaminy Creek at valley floor elevation 80. Storage to elevation 114 will serve as an 150-acre inactive pool. Maximum storage will flood 1,900 acres of land and water, including 13 miles of Neshaminy Creek, 6 miles of Little Neshaminy Creek, and 5 miles of Mill Creek. Although the maximum storage will be achieved at various times, the normal operating pool will be some 30 percent smaller with a surface area of about 1,375 acres.

76. Maiden (Moselem). -- This will be a multiple-purpose reservoir for water supply, low flow regulation and flood control. The unit will be located in Berks County, Pennsylvania. The dam site is at elevation 310 in the Maiden Creek valley, just upstream from Lake Ontelaunee. The planned inactive pool will flood 250 acres to elevation 322. The full water supply and low flow regulation pool, elevation 378, will inundate a total of 2,350 acres of land and water, including 6.5 miles of Maiden Creek. Normal operating conditions will form a reservoir pool averaging about 1,720 acres in surface area. Storage between elevations 378 and 397 is allocated to flood control purposes. The full reservoir will cover 3,500 acres including 9 miles of Maiden Creek.

77. French Creek. -- This unit is planned for water supply, low flow regulation, and flood control purposes. It will be located on French Creek in Chester County, Pennsylvania. The dam site is at valley floor elevation 210 on the French Creek, some 6 miles west of Phoenixville. The designed inactive pool will cover 100 acres at elevation 240. The maximum water supply and low flow regulation pool will inundate 1,120 acres of land and water including 4.6 miles of French Creek, .7 of a mile of Beaver Run and .5 miles of South Branch. The average size of this pool will be 815 acres under anticipated operating conditions. The full reservoir, including total flood storage, will have a surface area of 1,600 acres. There are 5 miles of French Creek within the designed maximum flow line of this reservoir.

78. Evansburg. -- The Evansburg unit is planned for water supply, low flow regulation, and flood control purposes. The reservoir site is 5 miles northwest of Norristown in Montgomery County, Pennsylvania. The dam will be built across the Skippack Creek valley floor at elevation 95. A 190-acre pool will be formed at elevation 125, the portion of the unit capacity set aside for inactive or reserve storage. The full water supply and low flow regulation pool will cover 1,200 acres including 6.7 miles of Skippack Creek and 1 mile of Towamencin Creek. Under normal operating conditions this pool will have a surface area of 900 acres.

At maximum pool elevation 180 the surface area of the reservoir will be 2,170 acres. A total of 8.2 miles of Skippack Creek, 1.5 miles of Towamencin Creek, and 1 mile of Zacharias Creek are included in the total reservoir.

79. Newark. -- This reservoir is planned for water supply and low flow regulation purposes. The dam site is at elevation 76 on White Clay Creek about 1 mile north of Newark, Delaware. The reservoir formed will extend across the State line into Chester County, Pennsylvania. The designed inactive pool to elevation 94 will have a surface area of 110 acres, all in Delaware. The full reservoir, elevation 156, will cover 1,060 acres, including 660 acres in Delaware and 400 acres in Pennsylvania. About 5 miles of White Clay Creek will be inundated by maximum storage, including 2.7 miles in Delaware and 2.5 miles in Pennsylvania. Under normal operating conditions the pool will average about 775 acres in surface area; 475 acres in Delaware and 300 acres in Pennsylvania.

Coastal Plain Section

80. Christiana. -- The Christiana Reservoir will be a water supply and low flow regulation unit just south of Christiana, Delaware. The dam site is at elevation 8 on the Christiana River. The planned inactive pool at elevation 23 will inundate 200 acres including the 25-acre Smalley's Pond. The full operating pool will flood 2,900 acres to elevation 49. Included in this acreage will be two 25-acre impoundments (Becks Pond and Sunset Lake), 5.8 miles of the Christina River, 4.5 miles of Muddy Run, and 3.1 miles of Belltown Run. The average size of the normal operating pool will be 2,000 acres.

Alternatives or Additions

81. The planning agency states that comprehensive development of the Basher Kill unit and Knights Eddy Reservoir might provide suitable benefits to be used as separate alternatives for 7 of the individual reservoirs of Phase II (Hawk Mountain, Paulina, Pequest, Hackettstown, New Hampton, Tohickon, and Newtown). Detailed studies concerning the feasibility of these alternatives will be made at some future date.

SECTION IV. - FISHERY RESOURCES

Without-the-Project 5/

Fresh Water Fishes

82. Cold-Water Fishes. -- The designation "cold-water fishes" 6/ as used in this report refers almost exclusively to the most important three species, brook, brown, and rainbow trouts. The terms "cold-water fishery" and "cold-water stream(s), lake(s), pond(s)", etc., as here used, imply that one or more of the above species are the principal inhabitants or the principal objects of fish management in the water, whether these species exist as natural or artificially stocked populations. In summary, unless otherwise indicated, the phrase "cold-water" refers to the species mentioned rather than to the complex of physical, chemical, and biological factors, including temperature in a body of water, which would ordinarily justify its use. So many streams whose environmental properties, including temperature, would normally warrant their classification as warm-water streams or streams on the borderline between the warm-and the cold-water condition are stocked with trout(s) in response to public demand that the revised definition is necessary.

83. Of the three sections of the Delaware River Basin, the Upland Section contains the most important and the most abundant cold-water fisheries. Several factors account for this situation: cooler temperatures resulting primarily from the generally higher and more rugged terrain; a larger number of streams, lakes, and ponds; less application of land and water use practices usually destructive of cold-water fishery habitat, such as land clearing and associated soil erosion and reduction in cover in the watersheds; intensive agricultural practices on extensive areas; extensive industrial, urban, or suburban development; and stream pollution. An inventory and classification of the cold-water fishery resources of the Delaware River Basin, prepared for this study, is presented in table 3 for the 12 subbasins (See figure 2). Classification of the Fishery resources was based upon quality of habitat and/or degree of utilization by fishermen. Class I, Class II, and Class III indicate decreasing order of importance. Class IV indicates bodies of water having good basic physical characteristics but having lost their

5/ As used in this report, "Without-the-Project" and "With-the-Project" actually means without or with the entire plan with all its individual projects.

6/ Others, less important in most waters, or, of significant importance in local areas, are: blacknose dace, sculpins, red and Atlantic salmon, splake, and lake trout.

fishery value because of pollution. In table 4 similar data are given for the Upland, Piedmont, and Coastal Plain Sections through recompilation of the data in table 3. In figure 4 the geographic distribution of the 4 classes of fisheries, both cold-and warm-water streams, lakes, ponds, and reservoirs, may be better visualized.

Table 3.--Classification of fishery resources - Delaware River Basin

	Lakes and Ponds (acres)				Rivers and Streams (miles)			
Subbasin	Class I	Class II	Class III	Class IV	Class I	Class II	Class III	Class IV
1 - 2	7,400	8,100	650	0	450	173	77	0
3 - 4	11,900	4,000	700	0	460	391	339	0
5	1,950	1,740	10	0	381	213	211	59
6	5,260	840	0	0	124	111	85	0
7	1,550	150	300	0	276	219	390	83
8	0	75	488	0	16	216	78	9
9	0	175	25	0	35	35	89	0
10	870	150	2	0	153	94	205	24
11	400	40	80	0	0	18	51 1/	24 2/
12	1,270	870	320	0	159	47	0	0
13	1,770	50	0	0	89 3/	80	7 1/ 3/	10 2/ 3/
TOTAL	32,370	16,190	2,575	0	2,143	1,597	1,532	209

1/ Twenty-eight miles of totals shown are in Class III, representing each side of the Delaware River between the Benjamin Franklin and Delaware Memorial Bridges.

2/ Twenty-eight miles of totals shown are in Class IV, representing the center zone of the Delaware River between the Benjamin Franklin and Delaware Memorial Bridges.

3/ Nine miles (not listed in table), comprising the Delaware River between Delaware Memorial Bridge and the south end of Pea Patch Island, consist of transition zone between Delaware Bay (Class I) and the River (Classes III and IV).

Table 4.--Classification of fishery resources by sections

Physiographic Section	Lakes and Ponds (acres)				Rivers and Streams (miles)			
	Class I	Class II	Class III	Class IV	Class I	Class II	Class III	Class IV
UPLAND								
1 - 2	7,400	8,100	650	0	450	173	77	0
3 - 4	11,900	4,000	700	0	460	391	339	0
5	1,156	1,032	6	0	226	126	125	36
7	335	32	65	0	60	47	84	18
Total 1/	20,791	13,164	1,421	0	1,196	737	625	54
PIEDMONT								
5	794	708	4	0	155	87	86	24
6	5,260	840	0	0	124	111	85	0
7	1,215	118	235	0	216	172	306	65
8	0	64	413	0	14	183	66	8
9	0	55	8	0	11	11	28	0
10	838	144	2	0	147	90	197	23
Total 1/	8,107	1,929	662	0	667	654	768	120
COASTAL PLAIN								
8	0	11	75	0	2	33	12	1
9	0	119	17	0	24	24	61	0
10	32	6	0	0	6	3	8	1
11	400	40	80	0	0	18	51 2/	24 3/
12	1,270	870	320	0	159	47	0	0
13	1,770	50	0	0	89 4/	80	7 2/ 4/	10 3/ 4/
Total 1/	3,472	1,096	492	0	280	205	139	36
GRAND TOTAL 1/	32,370	16,189	2,575	0	2,143	1,596	1,532	210

1/ See Footnote No. 1, Table 10
2/ See Footnote No. 1, Table 3
3/ See Footnote No. 2, Table 3
4/ See Footnote No. 3, Table 3

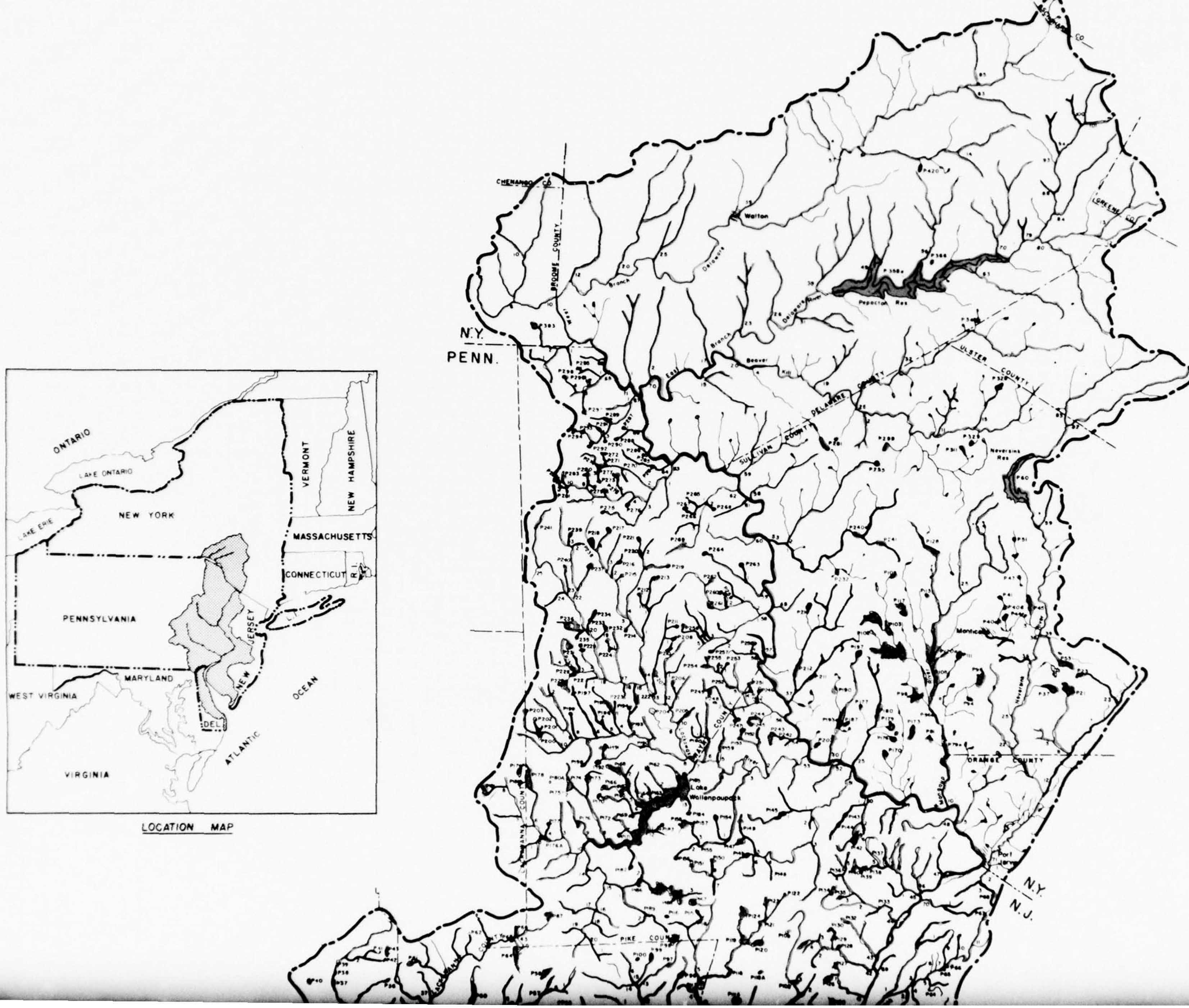
84. As indicated in table 4, cold-water fisheries are present in a large proportion of the stream mileage and in the lake and pond acreage, natural and artificial, within the Upland Section. These streams range in size from small feeder tributaries to the Delaware River main stem; and the lakes and ponds, from less than 10 acres to Lake Wallenpaupack and Pepacton Reservoir.

85. Of the cold-water fishes present in waters of this section (in fact, in basin), lake, brown, and rainbow trouts, red salmon, and splake are introduced species.

86. Although natural reproduction of rainbow trout is limited both in numbers and occurrence, that of brown and brook trouts is common in many of the Upland waters. Some of the more important streams in which natural spawning occurs are Shingle Kill, Basket Creek, Mongaup River, Mill Brook, Callicoon Creek, Tenmile River, Coles' Clove Brook, Beaver Kill, East Brook, East and West Branches of the Delaware River, Little Delaware River, and Neversink River and its tributaries in New York; Flat Brook in New Jersey; and Paradise, Pocono, South Fork Wallenpaupack, McMichaels, Broadhead, and Stoney Creeks in Pennsylvania. In addition to this natural reproduction, hundreds of thousands of brook, brown, and rainbow trouts are stocked annually in hundreds of miles of these streams and in many others, as well as in thousands of acres of lakes and ponds in the Upland Section in New York, Pennsylvania, and New Jersey where water conditions are suitable, to provide fishable populations for anglers. Lake trout have been introduced into a number of lakes in Subbasin No. 3-4 but survival has been only mediocre. A good population of red salmon has been established by stocking in Lake Oquaga (New York); splake have also been stocked in this lake. Atlantic salmon have been stocked in Neversink Reservoir.

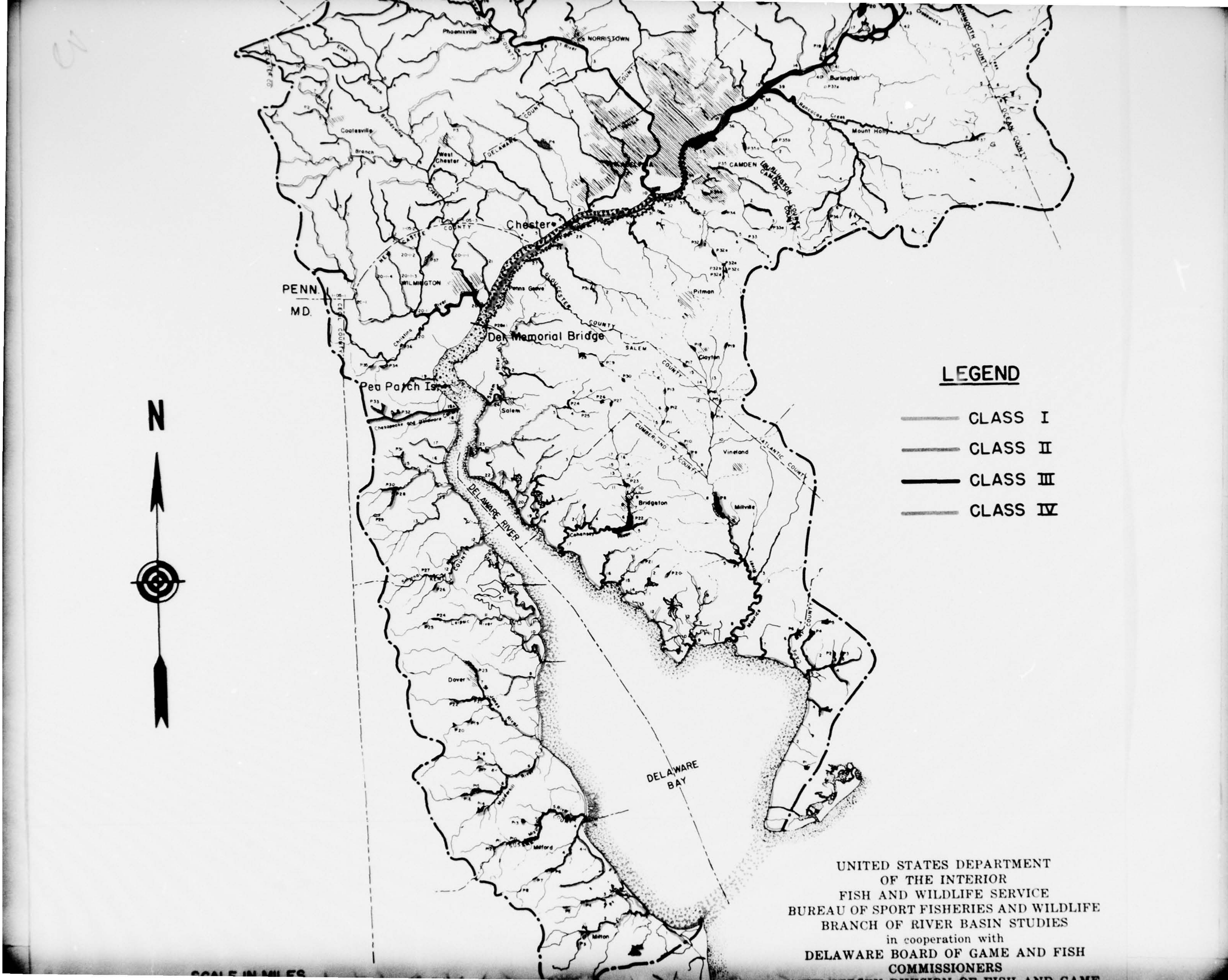
87. While some reservoirs such as Pepacton and Neversink contain large numbers of brown trout which support popular trout fisheries, impoundment of these same waters, including also Swinging Bridge and Toronto Reservoirs, has caused destruction or deterioration of trout stream fisheries. Environmental changes in the waters induced by impoundment have favored the predominance of warm-water fishes within the reservoirs themselves, and have resulted in migration of warm-water species upstream where they now compete with trout in waters formerly more favorable to the latter.

88. Reservoir construction has influenced stream fish habitat in another manner. Release of cold water from Pepacton Reservoir on the East Branch Delaware River has caused a change in habitat below that dam on the East Branch and on a segment of the Delaware River main stem to Lackawaxen, Pennsylvania. This reach, formerly important for its smallmouth bass fishery, has now become more



CHENANGO CO.
BROOME COUNTY
GREENE CO.
Walton
Pepacton Res.
Delaware River
East Branch
Beaver Kill
ULSTER COUNTY
DELAWARE COUNTY
SULLIVAN COUNTY
Neversink Res.
Monticello
ORANGE COUNTY
Lake Wallenpaupack
PIKE COUNTY
N.Y.
PENN.
N.Y.
N.J.
ONTARIO
LAKE ONTARIO
LAKE ERIE
NEW YORK
VERMONT
NEW HAMPSHIRE
MASSACHUSETTS
CONNECTICUT
R.I.
PENNSYLVANIA
NEW JERSEY
MARYLAND
WEST VIRGINIA
DEL.
VIRGINIA
ATLANTIC
OCEAN
LOCATION MAP

LOCATION MAP



LEGEND
CLASS I
CLASS II
CLASS III
CLASS IV
N
PENN.
MD.
Chester
Del Memorial Bridge
Pea Patch Is.
DELAWARE RIVER
DELAWARE BAY
NORRISTOWN
Phoenixville
Coatesville
West Chester
WILMINGTON
CAMDEN
Burlington
Mount Holly
Pitman
Clayton
Salem
Vineland
Bridgeton
Millville
Dover
Milford
Milton
GLOUCESTER COUNTY
SALEM COUNTY
CUMBERLAND COUNTY
ATLANTIC COUNTY
OCEAN COUNTY
MONMOUTH COUNTY
UNITED STATES DEPARTMENT
OF THE INTERIOR
FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE
BRANCH OF RIVER BASIN STUDIES
in cooperation with
DELAWARE BOARD OF GAME AND FISH
COMMISSIONERS

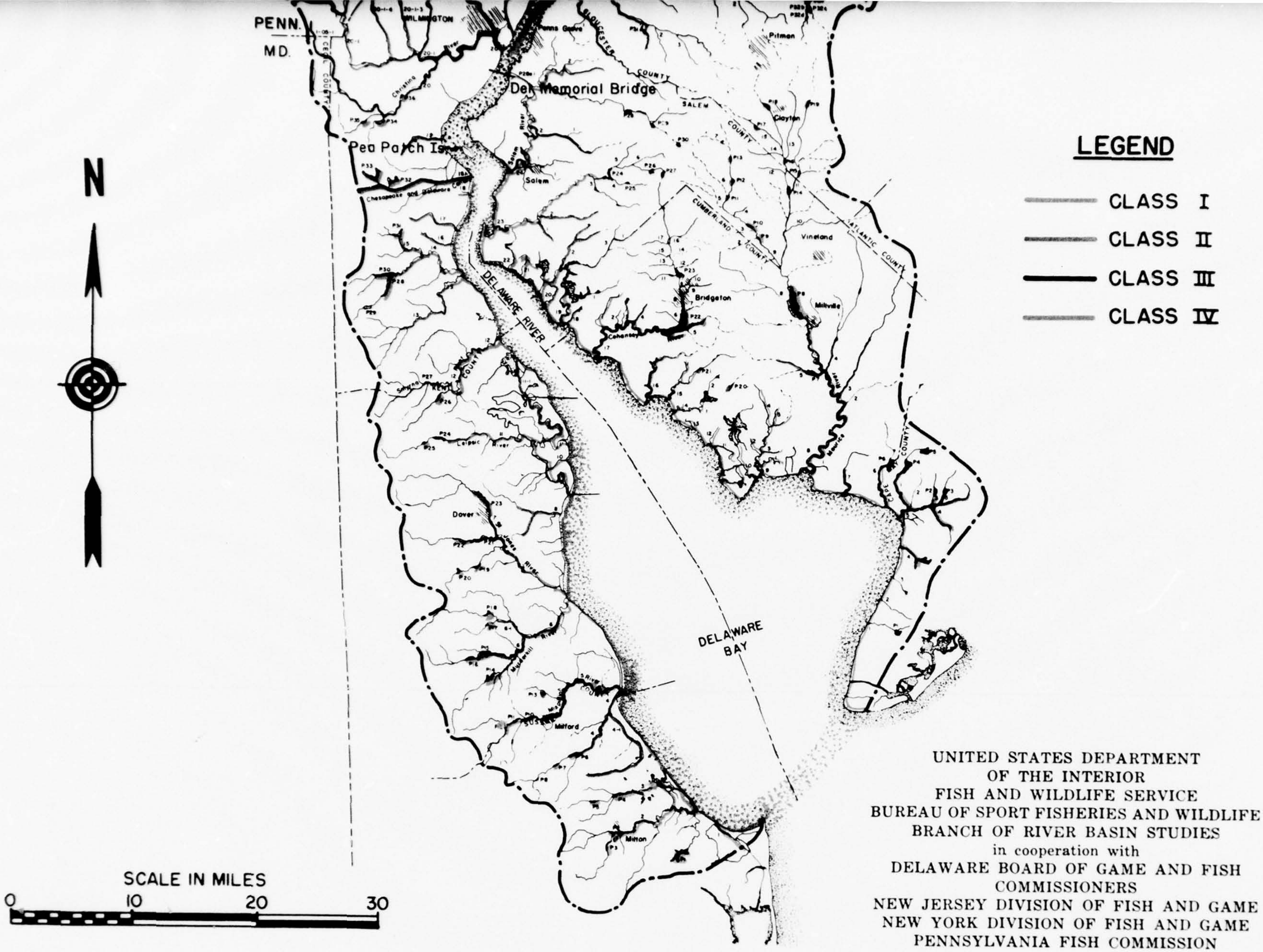


Figure 4. – Fisheries classification map Delaware Basin

suitable for trout. This is at once both a gain and a loss depending on whether the interests of trout fishermen or bass fishermen are considered paramount. The probable release of very cold water also from Cannonsville Reservoir, now under construction on the West Branch Delaware River, will convert this section of river to a trout stream and may extend the present trout-type water on the main stem, perhaps to the mouth of the Neversink River at Port Jervis.

89. Despite the importance of the stream fisheries of this section, fish productivity is less than ideal, varying from excellent to poor as it does in numerous eastern United States streams. Many of these streams are lacking in fertility; suffer from deficiencies in food; and have poorly balanced fish populations. The quality is further depreciated by unfavorable physical characteristics, including a shortage of pools, riffles, bottom cover, and shade-creating bank vegetation.

90. Among the lake and stream fisheries in the Upland, utilization ranges from extremely heavy to very light. Without question, the heaviest utilization is experienced in fisheries where trouts occur, notwithstanding the abundance of and interest in the warm-water fisheries. The cold-water streams mentioned earlier, together with Trout Brook, Willowemoc Creek, and Bushkill Creek in New York, and the Lackawaxen River, Bushkill, Shohola, Dyberry, Saucon, Pohopoco, Bear, and Locust Creeks in Pennsylvania, constitute the best and most heavily utilized trout streams of the Upland Section. Of these, the Neversink River, Beaver Kill, and Willowemoc, Bushkill (Pa.), Brodhead, and Shohola Creeks rank highest in trout fishermen interest, attracting many people from within and outside the Delaware River Basin. The Upland trout fisheries are one of the major factors supporting the reputation of this portion of the basin as an outdoor recreation area. Their utilization will increase in the future as the population increases, and with it the associated demand for more of this type of recreation.

91. Underutilization of Upland lake, pond, and stream fisheries, including cold-water fisheries, occurs in many places. This underutilization is accounted for in many places by the exclusion of the public from privately-owned streams, lakes, and ponds, and adjoining lands and by the physical inaccessibility of many of these waters except to those who hike to them.

92. Turning now to the Piedmont Section, the cold-water fisheries consist mostly of brook, brown, and rainbow trouts, and are less abundant than those in the Upland part of the basin. A larger proportion are found in streams than in lakes and ponds, with both types being more numerous in the upper half of the Piedmont. Tables 3 and 4 show the extent and classification of these fisheries.

93. A number of the streams of the section, especially in the southern half, contain natural trout populations, although few of these contain trout fisheries capable of sustaining populations large enough to attract and hold the interest of fishermen when unaided by stocking. In other words, without artificial stocking, trout fisheries would be totally inadequate to meet the fisherman's demands. In the Brandywine Subbasin, for example, nearly all of the cold-water fishery is maintained by stocking.

94. Physical, chemical, and biological conditions in the streams are also considerably less than ideal in this portion of the basin. Contamination by acid-coal-mine drainage, mostly in the Lehigh and the upper part of the Schuylkill Subbasins, and pollution by municipal and industrial wastes in many of the streams elsewhere, are 2 of the important existing stream conditions.

95. Heavy fishing pressure during trout season is characteristic on many of the Piedmont cold-water streams. These include the Lehigh River, Beaver, Birch, Buck, Rock, and Broad Runs, Saucon, Little Lehigh, Bushkill, Wissahickon, French, Sacony, Pine, Tulpehocken, Spring, Hay, Pennypack, Neshaminy, White Clay, Chester, Valley, and Pocopson Creeks in Pennsylvania; the Musconetcong and Pequest Rivers, the Paulins Kill, and Assunpink, Alexauken, and Wickecheoke Creeks in New Jersey. Casual observation indicates that lakes and ponds generally receive considerably less public fishing pressure than streams.

96. Many waters are closed to public fishing. Most of these are in private ownership; some, including several municipal water supply reservoirs, are in public ownership.

97. Finally, considering the cold-water fisheries of the Coastal Plain Section, we find they are considerably more limited in number and area than in the Piedmont Section (tables 3 and 4). None are available in the Delaware Coastal and few in the New Jersey Coastal Subbasins. Existing cold-water fisheries of all types, in this section, are maintained almost completely by artificial stocking of brook, brown, and rainbow trouts.

98. The most heavily utilized trout streams are Back, Big Lebanon, and Berryman's Runs, and Doctor's, Menantico, Big Timber, Ellisburg, and Woodcrest Creeks in New Jersey. Over 25 small lakes and ponds, all of which are in New Jersey, provide trout fishing. The most noteworthy of these is Swedesboro Lake in Subbasin No. 11. This shallow 21-acre lake formerly was overrun with pan and rough fish; in 1955 it was reclaimed and stocked both in 1955 and in 1958 with fingerling rainbow and brown trouts. In this heavily-utilized lake, the stocked fish survived well and have produced satisfactory populations of individuals ranging from 10 to 15 inches in length. The trout, however, suffer continuing competition from sunfish species.

99. It appears that the cold-water fisheries open to public fishing in the Coastal Plain Section are being utilized at or close to their maximum potential.

100. The principal problems in managing the cold-water fishes of the Delaware River Basin are outlined below:

(1) The habitat quality of a number of streams, lakes, and ponds, mostly in the Upland and secondly in the Piedmont Section, has deteriorated and/or is deteriorating so that the capability of the resource to meet present and future needs is impaired. This deterioration results from numerous causes, natural and man-made. Among these are: natural changes resulting from geologic and plant succession, severe storms such as hurricanes which damage streams and lakes by scouring, flooding, sedimentation, etc., and man-caused changes resulting from current malpractices in logging, deep coal mining and strip-mining, road construction, stock grazing and other watershed land-use which produce effects similar to severe storms and from introduction of inferior fishes which compete for food and cover with the more desirable species. The strip-mining effects are most apparent on the headwaters of the Lehigh and Schuylkill Rivers, in which coal-washing deposits are commonplace.

(2) Sewage, domestic and industrial wastes, both physical and chemical, are adversely affecting cold-water fish populations, often inhibiting or greatly reducing their productivity, growth, and health. This problem is most common and serious in and near populated centers but it frequently extends downstream for long distances. Figure 4 shows the locations of the principal waters of the basin in which such pollution is a problem (Class IV waters). Pollution is a more serious problem in the Piedmont and Coastal Plain Sections than in the Upland Section.

(3) A stream habitat problem of local importance will occur in the Paulins Kill, in northwestern New Jersey, as a result of the completion of the Paulins Kill Small Watershed Project. A 3/4 mile section of this stream below Blairstown will be channelized for purposes of flood control upstream. This will significantly impair the important existing trout fishery in this reach if remedial measures are not taken. A similar problem exists on Lower Brodhead Creek in Pennsylvania, where the Corps of Engineers would undertake stream dredging.

(4) Impoundments constructed on cold-water streams, especially those large impoundments created since 1935, have eliminated many miles of trout stream fisheries. Reservoirs in this category include Pepacton, on the East Branch Delaware River; Swinging Bridge, Rio, and Toronto, on the Mongaup and its tributaries; and Neversink, on the Neversink River. At the same time warm-water reservoir fishing has been created and bottom releases have added trout fishing below such dams.

(5) In most cold-water streams, and to a lesser extent in lakes and ponds, the existing trout resources do not contribute so much as they should to satisfying public demand because their inherent capacity for production is limited. Aside from problems previously discussed, many streams have elevated temperatures resulting from poor summer flows and have poor pool and riffle development and most streams and lakes are deficient in food organisms. The problem is applicable to Upland and Piedmont cold-water fisheries and it may become so to Coastal Plain waters if public demand should dictate artificial establishment of trout fisheries in many of the waters naturally incapable of supporting them.

(6) Opportunities for public use of trout fisheries are limited on many streams, lakes, and ponds in the basin. This limitation has moderate to severe effects on fishermen use of these waters. It is caused primarily by one or both of the following conditions: (a) Posting of waters, or lands adjacent thereto, against public access; (b) lack or inadequacy of physical access and public-use facilities. Both exigencies cause underutilization of posted or inaccessible areas and frequently produce overutilization and overcrowding in open waters. Satisfying overall public demand for trout fishing is thus partly thwarted.

Most of the posted lands and waters are in private ownership, though some are publicly controlled. Inadequate access and use facilities include shortage of access roads, trails, and parking areas. This problem is prevalent both in the Upland and Piedmont Sections. It exists also in the Coastal Plain Section to a lesser degree, where fishing pressure often exceeds the limited capacity of the few open and accessible trout-stocked waters.

(7) There is a shortage of factual data required for proper management of cold-water fisheries in all sections, and especially in the Upland and Piedmont areas where the fisheries are most numerous and demand is heavy and widespread. Needed facts include identification of waters best suited to stocking; determination of the optimum numbers to stock in various waters, consistent with maximum utilization and financial consideration; and the most feasible methods of reclamation of waters to be rehabilitated; methods to control undesirable competing fish species and vegetation.

(8) Funds available to conservation agencies responsible for managing cold-water fisheries frequently cannot be used or are insufficient for such purposes as obtaining facts such as those mentioned in problem No. 7; acquiring lands and waters to provide more public fishing opportunity; or maintaining and enhancing trout fishery values, including proper and sufficient stocking programs.

(9) Public misinformation or lack of information on the merits and desirability of instituting proper fish management techniques often severely hampers public conservation agencies in managing cold-water fishery resources properly and economically. Determination and implementation of fishery management policies and programs by public agencies is particularly sensitive to public opinion; hence, this is a serious problem.

101. Warm-Water Fishes.[7] -- The chief species included under the designation "warm-water fishes" in this report are smallmouth bass, largemouth bass, pickerel, walleye, bullhead, catfish, numerous pan and forage fishes, carp and other rough fishes.

102. In the Upland Section the basses, pickerel, yellow walleye, and various pan fishes are the principal warm-water species represented. They occur in lakes, ponds, and streams, including many which are fished for cold-water species. Tables 3 and 4 are compilations of the lotic and lentic habitats of the subbasins and the physiographic sections of the basin, with further grouping by the classes of these environments.

7/ See first paragraph of the treatment of Cold-Water Fishes for explanation of the use of the term Cold-Water Species. This explanation applies equally to Warm-Water Fishes by substitution of word "warm" for "cold", except for species named.

103. Populations of these species are supported by natural reproduction. One or more of the species thrive in the lakes and ponds and in nearly all the streams of the area except some of those which are bona fide cold-water streams in terms of habitat quality. Some of the lakes providing warm-water fishing are Neversink, Pepacton, Toronto, Mongaup Falls, and Swinging Bridge Reservoirs in New York; and Lake Wallenpaupack, Promised Land, Twin, Porters, Sky Top, Hauto Dam, Parryville Dam, Harvey and Brady Lakes in Pennsylvania. The Delaware River is the principal stream providing warm-water species for anglers; smallmouth bass and yellow walleyes make up the bulk of the game fish catch. Other important warm-water streams are the lower sections of the Lackawaxen River and Brodhead Creek. Some streams, notably in the Upland portion of the Lehigh Subbasin, contain few fish because of pollution by acid mine-drainage and coal washings. An appreciable number of lakes, ponds, and streams are not open or not conveniently accessible to the public for fishing.

104. Although a large segment of fishermen interest is centered on the cold-water fishes in this section, a considerable share of the total annual fish catch is comprised of the less commended and less advertised warm-water species. Compared with cold-water fishes, relatively few numbers of warm-water fishes are stocked in waters of the section to help satisfy public demand. Also, stocking of these species is confined to a comparatively small number of waters, primarily in the Lehigh Subbasin.

105. Going to the Piedmont Section, we find that nearly all the lakes, ponds, and streams contain warm-water fishes; in fact, these waters are better suited to such fishes than to trouts for natural reproduction and growth, making it unnecessary in most habitats to stock them. The amount of warm-water fish habitat by classes is presented in tables 3 and 4.

106. The species present in these waters are largely the same as those mentioned for the Upland Section. Similarly, one or more of the leading warm-water game fishes, the smallmouth and largemouth basses, and pickerel, are also predominant among game fishes in this section; yellow walleye should be included in this category in a limited number of waters, including the Delaware River from the northern to the southern limits of the Piedmont Section. These species are subjected to considerable fishing pressure; however, the more abundant pan fishes, including bluegill and crappie, the rough fishes, such as the carp, and the forage fishes, including suckers, account for the bulk of the annual catch and receive much heavier pressure each year. Greater productivity in point of weight and numbers is not the sole reason for the pre-eminent position of warm-water over cold-water fishes in fisherman attention and size of annual catch in this section. Season lengths, and bag and minimum size limits on pan, forage, and rough fishes for hook-and-line anglers are far more liberal in waters of this section, as well as in other sections and States of the basin, than those for trout.

107. In Pennsylvania, some of the lakes most popular as warm-water fisheries include East Bangor (Dam), Tibbet Swamp, Lake Ontelaunee, Deep Creek, Hopewell, Silver, and Warren Lakes; in New Jersey, Lake Hopatcong, Mirror Lake and the Medford Lakes. A few of the important streams, in addition to the Delaware River, are portions of the Lehigh River, Neshaminy, Little Neshaminy, Brandywine, Ridley, and Darby Creeks in Pennsylvania; and the Paulins Kill and the Musconetcong River in New Jersey. To augment the number of warm-water fishes available to anglers, a few of the waters of the Piedmont Section are stocked, mostly with basses, pickerel, and catfish. In at least one State, New Jersey, warm-water fishes are stocked only in reclaimed waters; i.e., waters in which undesirable species have first been eradicated.

108. A number of lakes, ponds, streams, and segments thereof, chiefly in private ownership, are closed to public fishing; one publicly-owned body of water in this category is Churchville Reservoir, in Bucks County, Pennsylvania, used as a public water-supply source.

109. As in the Piedmont Section, the waters of the Coastal Plain Section generally are well suited to and well supplied with warm-water fish populations. With the possible exception of the smallmouth bass and yellow walleye, the same species inhabit these waters. Stocking of lakes, ponds, and streams is resorted to very sparingly because of the adequate natural productivity; occasionally, species are stocked to establish populations in reclaimed waters. The amount and classification of warm-water fisheries in this section are depicted in tables 3 and 4. Largemouth bass and pickerel, among the game fishes, and the previously mentioned pan, rough, and forage fishes account for the bulk of the annual catch and receive the greatest fishing pressure.

110. The habitat quality of the stream fishery of the Coastal Plain Section has deteriorated somewhat during the past several decades, though not more, generally speaking, than stream habitat in the Piedmont Section. Past and, in some cases, continuing deleterious land and water use practices are responsible such as: improper agricultural practices leading to excessive soil erosion and consequent stream siltation; channelization; excessive runoff from poor land-use practices in the several watersheds; and use of the streams as receptacles for municipal sewage and industrial wastes, to name a few. Special mention should be made of the pollution load in the segment of the Delaware River between Torresdale, Pennsylvania and Pea Patch Island, Delaware, which seriously reduces the fish productivity of the river in this area.

111. Another habitat condition which is not desirable is the natural acidity of lakes and ponds in portions of the section within New Jersey, and, to a lesser extent, in Pennsylvania. This acidity is derived from the soil and vegetation and is conveyed to these lakes and ponds by ground water.

112. The major problems of warm-water fish resources crystallized from this basin-wide study are as follows:

(1) Naturally-acid ground waters supply a number of lakes within the Coastal Plain portion of New Jersey and parts of Pennsylvania with water of the same character. Such chemical conditions have prevented game-fish production, notably largemouth bass, in these lakes.

(2) The pollution problem as described under Cold-Water Fishes is applicable to warm-water species also. It should be added that certain types of pollution favor the dominance of undesirable rough fishes capable of survival in such environments. These fishes compete with the more popular warm-water (and cold-water) species for food and space. Many fresh water streams are contaminated, including those tributary to the lower Delaware River and Delaware Bay, which are tidal in their lower reaches. Tides carry pollution from the River and the Bay into these tributary streams, thus adding to whatever pollution load they might be carrying which originated above tidewater. The pollution problem probably will remain serious and may increase in severity unless remedial measures are taken, in view of the increase in human populations, industrial expansion, and attendant increases in domestic and industrial waste disposal into basin streams.

(3) Downstream from dams constructed on streams which supported warm-water fishes prior to impoundment, the water will become more suited to natural cold-water fisheries, particularly below high-dam reservoirs if provisions for bottom water releases are made. Although favoring the trout fishing enthusiasts, obviously this means a loss in resources available to meet the demands of fishermen whose preference is for warm-water species. The warm-water stream fisheries within the impounded portion of the site will, of course, be destroyed, but compensating reservoir fishing values would be brought about.

The downstream condition described above has already occurred below Pepacton Reservoir on the East Branch

Delaware River, as described earlier in the Fishery Resources Section. The probable, augmented cold-water effect downstream from Cannonsville Reservoir under construction on the West Branch Delaware River when the reservoir is placed in operation has also been discussed previously. Whether this problem would be as clear cut in connection with new reservoir sites in the Piedmont and Coastal Plain Sections as it is actually and appears potentially in the Upland Section is conjectural at this time.

(4) A shortage of lakes, ponds, and streams suitable for public warm-water fisheries exists in the basin. The problem is most applicable in the Piedmont and Coastal Plain, and to a more limited degree, in the Upland Sections. It is in reality a composite of Cold-Water Fishes problems Nos. 1, 5 and 6, with emphasis in problem No. 6 on the posted lands and waters aspect. Publicly-controlled waters, mainly municipal water supply reservoirs, as well as many privately-controlled waters are closed to public fishing. More access facilities are needed for public warm-water fishing on both banks of the Delaware River, especially in the Piedmont Section.

(5) The shortage of known facts needed for proper management of warm-water fisheries of the basin is as important a problem for this type of fishery as for cold-water fisheries. The discussion of this situation under Cold-Water Fishes, problem No. 7, is pertinent here, with some additions. In this case, the Piedmont and Coastal Plain Sections are chiefly affected. The types of data required for warm-water fisheries management include also proper size limits on fish caught and the determination of proper species combinations and stocking ratios, as well as the timing of their stocking in warm-water impoundments.

(6) Cold-Water Fishes problem No. 8, previously set forth, is also applicable to warm-water fisheries.

(7) Cold-Water Fishes problem No. 9, is outlined previously, applied equally to warm-water fisheries.

Marine Fishes

113. The portion of the Delaware River Basin in which marine finfish and shellfish are found, at least during part of their life cycles, include the river and some of its tributaries and the estuary.

That part of the estuary - diluted sea water - within the ocean consists of a 2,000 to 3,000 square mile coastal area outside and mostly south of the entrance to Delaware Bay, roughly, to the 100-fathom contour and Chincoteague Inlet, Virginia.

114. This geographical area, constituting the Delaware Bay Subbasin, supports coastal fisheries which are among the most productive in North America and, perhaps, in the world. It is the geographical center of distribution for migratory fish stocks ranging between Cape Cod and Cape Hatteras, and it is considered the southern range limit of northern marine species and the northern limit of southern species inhabiting the eastern coastal waters of the United States. More than 200 finfish species alone are known to inhabit the subbasin.

115. There are many unknown or partially unknown factors accounting for the biological productivity of Delaware Bay. From what is known however, some generalized reasons for the high value of the bay fisheries can be derived. Characteristic of most of the productive estuaries, the bay is an area where fresh waters laden with nutrients from soils of the basin mingle with plankton-rich sea waters. Compared with the coastal waters of the open ocean, waters of the bay are exposed to less dilution through tidal cycles; hence, in the estuary, greater concentrations and chemical exchanges of nutrients can occur. The bay is shallow with broad expanses of bordering tidal marshes and flats. Important and abundant nutrients from the shore marshes, guts, and inflowing streams are flushed by tides into the bay where they combine with those of the Delaware River and its tributaries, already mentioned. Within the subbasin, the only area generally of less than Class I fishery importance is the segment of the Delaware River between Chester, Pennsylvania and Pea Patch Island. From the northern end of this reach to Delaware Memorial Bridge, the river habitat is of Class III and IV importance; the remainder of the segment, i.e., from Delaware Memorial Bridge to Pea Patch Island, is a recovery zone varying from Class I to Class III in importance as fishery habitat.

116. The Delaware River Estuary, like others, is characterized by a wide range of environmental conditions and habitats. This diversity may be beneficial and even indispensible to the inhabiting species, such as the blue crab and the oyster. A static condition of these environmental factors and habitats is impossible in an estuary. The sequence of estuarine habitats and biota and the net seaward flow of water form the complex of biological productivity from river to ocean. Quite possibly, reduction or elimination of one of the local habitat types will affect all or nearly all of the productive capacity of the estuary, since total productivity may well be dependent in large measure upon the contributions of the total environment's component parts. The marine fisheries of the estuary are potentially, and actually to a lesser degree, very productive. Actual productivity is limited to varying degrees by exposure of the inhabiting species to

numerous decimating factors and adverse influences. Among the primary factors are storms; sedimentation; dredging and filling operations; industrial, municipal, and agricultural expansion within the basin, including the lands proximate to subbasin waters; use of pesticides; pollution (the potential influence of radio-active waste products as pollutants should not be overlooked); and biological agents such as diseases, parasites, and predation on eggs and larval stages of these marine species. The recent great oyster mortality in Delaware Bay had its origin in parasitic infestation.

117. The marine finfish and shellfish of the area have high commercial value. During the most recent 6-year period on record, 1951-56, the general trends in total tonnage of fish landed in New Jersey and Delaware has risen from approximately 412 million pounds in 1951 to 890 million pounds in 1956, although the annual rate of increase has not been constant. In 1955, fifty species of finfish and twelve species of shellfish were included in the total commercial catch. These included the following 6 species of finfish and 6 of shellfish, each valued at more than $100,000, listed in descending order by size of catch: menhaden, porgy, fluke, sea trout, sea bass, and croaker; eastern oyster, surf clam, blue crab, hard clam, sea scallops, and lobsters. Total commercial value of the catch is about $13,000,000 annually, with menhaden and oysters comprising over half the total.

118. Six major ports of landing, 5 of which are located fairly close to the mouth of Delaware Bay, are used by commercial fishermen of the Middle Atlantic region. These 5 ports, whose relatively close proximity to the Delaware River estuary underscores the importance of the latter as a commercial fishery, are: Atlantic City, Wildwood, Cape May, and Bivalve, New Jersey, and Lewes, Delaware. The 1955 landings in the Delaware Bay Subbasin included approximately 22 percent of the menhaden, 13 percent of the eastern oysters, and 27 percent of the clams caught in Alaska and continental United States. In the same year, the continental United States ranked second among nations of the world in total catch of commercial fisheries, and one of its ports within the subbasin, Lewes, Delaware, where more than 308 million pounds of fish (mostly menhaden) were landed, ranked third among the nation's ports in total landings.

119. Commercial fishes provided employment for 3,216 regular and 1,070 part-time fishermen in the Delaware Bay Subbasin during 1955. Not only these fishermen but 204 wholesaling and manufacturing establishments in New Jersey, Delaware, and Pennsylvania, which engaged an average of 5,114 persons during the fishing season and an average of 3,301 persons for the year 1955, were dependent upon commercial fisheries. In the same year these establishments produced more than 50 million dollars worth of manufactured fishery products.

120. The high regard for the recreational value of the marine fisheries of the area is attested by the approximately 130,000 salt water sport-fishermen who devote some 900,000 man-days to fishing within the Delaware Bay Subbasin each year. These persons are mostly fin fishermen but large, though uncounted, numbers of individuals also engage in non-commercial clamming and crabbing. The 6 finfish species which account for the largest annual harvests by sport fishermen are (in descending order): bluefish, porgy, weakfish, fluke, sea bass, and croaker.

121. Within the subbasin in 1955, more than 544 party and charter boats and 5,000 row boats were available to salt water sport-fishermen for hire. In addition, some 35,000 privately-owned craft, ranging from canoes to yachts, were used in salt water sport-fishing activities in this area during the same year.

122. As in the case of other fishery resources, there are problems involved in the management of the marine fisheries. The more important of these are given below:

(1) The conditions of environment, natural or man-caused, tending to reduce the productivity of each of the marine fishery resources, are an important problem. Further, the importance of these conditions is not correlated with the degree of their susceptibility to feasible control. Among them, listed not necessarily in order of magnitude, are: storms; sedimentation; dredging and filling operations; industrial, municipal, and agricultural expansion within the Delaware basin, including lands proximate to subbasin waters; use of pesticides; and pollution.

(2) Data available to those responsible for the policies and programs required to manage efficiently for commercial and recreational purposes the marine fishery resources are inadequate or lacking in many categories. These data include information on the physiology, pathlogy, life histories, population dynamics, and ecological relationships of many finfish and shellfish species. Much has been learned about these categories for various species through systematic research by many educational and industrial organizations, but much remains to be learned and disseminated where and when it can be best applied.

(3) Private facilities on Delaware Bay, upon which people depend heavily in pursuing their interest in the sport fisheries, are inadequate. These include boat launching and pier fishery facilities. Efforts by both New Jersey and Delaware to provide State-owned facilities

of the type mentioned have been made. Current demand for public boat-launching sites can be met in Delaware, which has provided a number of them in recent years opposite the better sport fishing grounds of the bay. The pier fishing installations are in short supply in both States. Week ends are the most critical periods of public demand. The need for such installations will probably increase.

(4) Too little information is readily available to the public on the questions of how, when, and where to attain the most enjoyment and use from the sport fisheries of Delaware Bay.

(5) Funds available to public and private organizations for compiling statistics and undertaking research and management projects required for the maximum utilization of marine fishery resources of the area are frequently inadequate or lacking.

Anadromous and Catadromous Fishes

123. Certain of the fish species, treated for convenience in presentation previously in this report as fresh, warm-water and/or marine fishes, are more properly designated from a physiological and ecological standpoint as anadromous or catadromous.

124. The anadromous fishes, whose most common representative species in the Delaware River Basin are shad, herring (alewife), striped bass, and white perch, live much of their life cycles in salt water and ascend fresh-water streams to spawn. These fresh-water streams include the Delaware River and its tributaries primarily, together with streams emptying directly into Delaware Bay.

125. The abundance of these fishes, including the principal species which is shad, has declined drastically in the fresh-water streams of the basin over a period of several decades to the present, insignificant, low level. In the case of the shad, for example, on which records of harvest over the years are probably the most complete of any of the species, the catch has declined from 13,368,000 pounds in 1901 to 76,000 pounds in 1954 in the Delaware River and Bay. The bulk of the catch in recent years has been taken in the bay, whereas in past decades, a large proportion of it was also made in the river from its upper reaches to its mouth.

126. One of the main reasons advanced for the fantastic decline in abundance of this and other anadromous species has been the generally increasing pollution load in the river during the period of fishery decline. Pollution has occurred in much of the river and

principal tributaries, but has been most severely limiting in its effect on fishes in the lower segment of the main stem between Torresdale and Marcus Hook, Pennsylvania. Low oxygen content of the water, accompanying the incidence of pollution, has apparently been very damaging to these species, especially during the fall of the year when the runs of adult and young fish to the ocean occur. The net effect has been a decline in abundance over the years to the point where the once thriving commercial fishing industry on the river, particularly for shad, no longer exists. Sport fishing for these species, also formerly a very popular pastime, has declined to a similar degree. Only a small number of any anadromous species have been caught on the Delaware River above Philadelphia during recent years. There is evidence, however, of increased numbers of shad, herring, and striped bass in the river within the last few years.

127. Catadromous fishes live much of their life cycles in fresh water and descend to the ocean to spawn. The eel is the only species in this category within the basin. Its numbers, in the same fresh water streams of the basin once harboring an abundance of anadromous fishes, have also declined drastically within recent decades.

128. Although the eel is still of commercial value in the basin, largely in the Upland portion, the size of the catch is only a fraction of what it was formerly.

129. In recent years, some 30 to 40 eel-chute licenses have been issued annually in the New York and Pennsylvania portions of this section. Recent total annual eel harvests have averaged 1,000 to 1,500 pounds. By comparison, during the period of abundance in the past, a reported 3,500 pounds have been taken annually in a single chute. Water pollution has apparently also taken its toll of eels in the Delaware River Basin.

130. The chief problems being confronted in the management of anadromous and catadromous fishes in the basin are:

(1) Present levels of water pollution in various segments of the Delaware River System, particularly in the main stem between Torresdale and Marcus Hook, Pennsylvania, are inimical to the productivity of shad, other anadromous fishes, and eels as outlined above.

(2) Existing dams on the lower portions of the Christiana River and Brandywine Creek in the Brandywine Subbasin prevent shad migration to and from these waters.

With-the-Project

Fresh-Water Fishes

131. Cold-Water Fishes. -- Construction of the Major Water Impounding Reservoirs in the Delaware River Basin will cause losses of 2 small cold-water lake fisheries below impoundment maximum pool levels in the approximate amount of 188 acres in the Piedmont Section of New Jersey.

132. Cold-water stream fishery losses in the form of habitat destroyed and unfavorably altered within the reservoir maximum pool levels will be more extensive and serious, as summarized in table 5. In addition, the Pequest Reservoir will eliminate a State trout rearing station, approximately 2 miles east of Buttzville, New Jersey. Not only will the existing hatchery facilities be lost, but so also will the station's superb water supply, a natural spring providing a daily flow of over 3 million gallons at 52° F. and without equal in quality and quantity anywhere else in the State.

133. Effects of reservoir construction on existing cold-water fisheries downstream from dam sites cannot be appraised accurately or categorically in the absence of data on probable volumes, frequencies, temperatures, and dissolved oxygen content of water releases. One generalization can be made at this time, however: Existing downstream fisheries will probably suffer losses unless with-the-project downstream conditions, in terms of the above elements, approximate pre-project stream conditions. There is small likelihood that this condition will occur or that benefits will accrue to with-the-project stream fisheries unless specific steps are taken to adjust reservoir operations to meet fishery requirements. Downstream cold-water stream mileage which will probably be affected adversely by reservoir construction is presented in table 5.

134. Completion of the Major Water Impounding Reservoirs will result in certain incidental benefits probably in the form of combined cold-and warm-water lake fisheries. The estimated acreages involved in these incidental benefits in the various sections and States of the basin are compiled in table 6.

Table 5.--Trout stream fishery losses

Phase & State	Miles Habitat destroyed				Miles Habitat unfavorably altered Fluctuation above dam				Miles Habitat unfavorably altered Flow & temp. below dam				TOTAL
	U	P	C	Total	U	P	C	Total	U	P	C	Total	
Phase I													
N.Y.	12.3	.0	.0	12.3	.0	.0	.0	.0	-	-	-	-	12.3
Pa.	66.2	15.4	.0	81.6	7.2	4.7	.0	11.9	9.5	3.7	-	13.2	106.7
N. J.	51.0	.0	.0	51.0	1.1	.0	.0	1.1	7.0	-	-	7.0	59.1
Del.	.0	.0	.0	.0	.0	.0	.0	.0	-	-	-	-	-
Total	129.5	15.4	-	144.9	8.3	4.7	-	13.0	16.5	3.7	-	20.2	178.1
Phase II													
N.Y.	33.3	-	-	33.3	-	-	-	-	7.0	-	-	7.0	40.3
Pa.	21.8	27.7	-	49.5	4.6	5.1	-	9.7	8.7 (+2 IV)	2.0	-	10.7	69.9
N.J.	-	34.8	-	34.8	-	-	-	-	-	10.7	-	10.7	45.5
Del.	-	2.7	-	2.7	-	-	-	-	-	3.4	-	3.4	6.1
Total	55.1	65.2	-	120.3	4.6	5.1	-	9.7	15.7	16.1	-	31.8	161.8
Total Phases I & II	184.6	80.6	-	265.2	12.9	9.8	-	22.7	32.2	19.8	-	52.0	339.9

Table 6.--Incidental fishery benefits - trout

Phase & State	Surface Acres Created Mainly trout water				Surface Acres Created Trout and warm-water species				Total Both
	U	P	C	Total	U	P	C	Total	
Phase I									
N.Y.	.0	.0	.0	.0	10,460.0	.0	.0	10,460.0	10,460.0
Pa.	.0	.0	.0	.0	3,730.0	.0	.0	3,730.0	3,730.0
N.J.	.0	.0	.0	.0	3,530.0	.0	.0	3,530.0	3,530.0
Del.	.0	.0	.0	.0	.0	.0	.0	.0	.0
Total	-	-	-	-	17,720.0	-	-	17,720.0	17,720.0
Phase II									
N.Y.	.0	.0	.0	.0	3,785.0	.0	.0	3,785.0	3,785.0
Pa.	.0	.0	.0	.0	.0	1,080.0	.0	1,080.0	1,080.0
N.J.	.0	.0	.0	.0	.0	4,305.0	.0	4,305.0	4,305.0
Del.	.0	.0	.0	.0	.0	.0	.0	.0	.0
Total	-	-	-	-	3,785.0	5,385.0	-	9,170.0	9,170.0
Total Phases I & II	-	-	-	-	21,505.0	5,385.0	-	26,890.0	26,890.0

135. Warm-Water Fishes.-- Creation of the Major Water Impounding Reservoirs in the basin will result also in small losses to existing warm-water lake fisheries. These include 2 small lakes totaling 166 acres in the Piedmont Section of New Jersey and three small lakes amounting to 75 acres in the Coastal Plain Section in Delaware. These lakes will be enveloped by the waters of the reservoirs.

136. Warm-water stream fisheries losses of the type just described under Cold-Water Fishes will also result. These losses in miles are shown in table 7.

Table 7.--Warm-water stream fishery losses

Phase & State	Miles Destroyed				Miles Altered above dam				Miles Altered below dam				
	U	P	C	Total	U	P	C	Total	U	P	C	Total	TOTAL
Phase I													
N.Y.	21.0	.0	.0	21.0	.0	.0	.0	.0	.0	.0	.0	.0	21.0
Pa.	52.9	12.4	.0	65.3	.0	4.2	.0	4.2	7.0	3.7	.0	10.7	80.2
N.J.	39.8	.0	.0	39.8	.0	.0	.0	.0	7.0	.0	.0	7.0	46.8
Del.	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	-
Total	113.7	12.4	--	126.1	--	4.2	--	4.2	14.0	3.7	--	17.7	148.0
Phase II													
N.Y.	9.0	.0	.0	9.0	.0	.0	.0	.0	7.0	.0	.0	7.0	16.0
Pa.	.0	54.0	.0	54.0	.0	7.7	.0	7.7	.0	12.2	.0	12.2	73.9
N.J.	.0	10.6	.0	10.6	.0	.0	.0	.0	.0	7.2	.0	7.2	17.8
Del.	.0	.0	5.8	5.8	.0	.0	.0	.0	.0	.0	4.0	4.0	8.8
Total	9.0	64.6	5.8	79.4	--	7.7	--	7.7	7.0	19.4	4.0	30.4	117.5
TOTAL PHASES I & II	122.7	77.0	5.8	205.5	--	11.9	--	11.9	21.0	23.1	4.0	48.1	265.5

137. Certain incidental benefits will be expected. The reservoirs will create, within their water supply and power pool zones, [8] lake fisheries suited principally to warm-water species but possibly favorable also to trout, depending on individual reservoir conditions. These probable incidental benefits are estimated in acres of habitat in table 8.

Anadromous and Catadromous Fishes

138. Only a few obvious possible effects on anadromous and catadromous fishes of the Major Water Impounding Plan for the Delaware River Basin can be set forth at the present time. Detailed studies on each reservoir project during the post-authorization phases prior to construction are needed to analyze these effects more thoroughly.

139. Whether implementation of the low flow augmentation provisions of this plan will alleviate the pollution problem as it currently affects the abundance of these species above Philadelphia cannot presently be predicted. If the adverse effects of pollution can be sufficiently eased between Torresdale, and Marcus Hook, Pennsylvania, to permit significant-sized runs of these species, especially shad, upstream and downstream along the main stem, the ecological and mechanical effects of main stream reservoir construction must then be appraised.

140. Although nearly all the proposed dams on streams in which these species could thrive will create physical barriers to their migration, the dam at Tocks Island will be the most critical barrier. If it were impossible to provide for safe passage of satisfactory numbers of fish upstream and downstream past this dam, there would be little point in attempting construction of passage facilities at the several dams upstream from the Tocks Island structure.

141. A major ecological problem could be the creation of thermal conditions adverse to the productivity of these species through reservoir construction at Tocks Island and other sites. Temperatures of tail waters in stream segments between dam sites and the back waters of downstream reservoirs, and perhaps within the deeper impoundments supplied by other reservoirs, may be below the threshold of acceptance for shad and possibly other species.

8/ Computed by taking 30% of the estimated acreage of this pool and subtracting the result from total estimated acreage of the reservoir to the top of the W.S. & P. pool.

Table 8.--Incidental fishery benefits - warm-water

Phase & State	Surface acres created - mainly warm-water species				Surface acres created - warm-water species with trout				
	U	P	C	Total	U	P	C	Total	TOTAL
Phase I									
N. Y.	0	0	0	0	10,460	0	0	10,460	10,460
Pa.	2,930	1,690	0	4,620	3,730	0	0	3,730	8,350
N. J.	0	0	0	0	3,530	0	0	3,530	3,530
Del.	0	0	0	0	0	0	0	0	0
Total	2,930	1,690	0	4,620	17,720	0	0	17,720	22,340
Phase II									
N. Y.	0	0	0	0	3,785	0	0	3,785	3,785
Pa.	2,575	5,480	0	8,055	0	1,080	0	1,080	9,135
N. J.	0	0	0	0	0	4,305	0	4,305	4,305
Del.	0	475	2,090	2,565	0	0	0	0	2,565
Total	2,575	5,955	2,090	10,620	3,785	5,385	0	9,170	19,790
TOTAL PHASES I & II	5,505	7,645	2,090	15,240	21,505	5,385	0	26,890	42,130

This condition could prevail especially if waters of the reservoirs are released through low-level outlets. Thus, these fishes may not be capable physiologically either of surviving migration or of spawning in sufficient numbers above the first main stem dam to assure a river fishery of any consequence.

142. One other problem should be sited at this time. The proposed schedules of downstream water releases from the dams, including Tocks Island, must be compatible with the requirements of the anadromous species, particularly during their upstream and downstream migrations. If flows should be cut off almost daily, so that stream beds would be practically devoid of flowing water in many reaches and would contain practically no attraction water for upstream migrants on segments immediately below fish passage facilities at dam sites, the success of vital fish runs would be in jeopardy.

SECTION V. - WILDLIFE RESOURCES

Without-the-Project

Big Game

143. The black bear is one of 2 big game animals inhabiting the Delaware River Basin. It is a wildnerness species found largely in the more extensive forested lands. Its range in the basin is confined almost exclusively to the Upland Section in New York and Pennsylvania. Estimates of the size of the bear population are not available; however, it is known to be small and has been fairly stable for the past few years.

144. Interest in the species is high among a relatively small segment of the hunter-public. It is higher, in fact, than would be expected for a game animal having as small a population and annual hunting season kill.

145. Available harvest figures for applicable subbasins in New York, Pennsylvania, and New Jersey are as follows: New York - subbasin No. 1-2 (1956, 1957), 20 and 26 were killed, respectively; Pennsylvania - subbasin No. 3-4 (1955, 1956), 56 and 45, - subbasin No. 5, 20 were killed in 1957; and in New Jersey, 8 were harvested in 1958, the first open season on bears in the State.

146. The whitetail deer is more widely distributed and in greater population density in areas having large amounts of forested and agricultural woodland and brushy cover types than in grassland and cultivated areas. Tree stands in immature rather than mature developmental stages are preferred. It is found also in many open farmlands especially when nearby woodland populations are high.

147. In addition to being the most important big game animal, the whitetail deer is also one of the most important of all game species in the basin. Its popularity among hunters has become high in many portions and is still increasing in some areas. Deer populations, harvests, and hunting pressure on the species are greatest in the Upland Section, considerably less in the Piedmont, and least in the Coastal Plain Section. Estimates within the last 3 years indicate that a 75,000 deer herd supported a kill of over 17,000 by some 120,000 hunters roughly within two-thirds (3,900 sq. mi.) of the Upland Section annually. Similar type data for the remainder of the basin are limited to a reported annual harvest of slightly over 2,500 deer in the Piedmont. Nearly all of the hunting pressure is exerted by gun hunters; a very small, though increasing, number of bow hunters to afield each year to hunt deer. Compared with the gun hunter kill, the annual harvest by bow hunters is extremely small.

148. Several important problems associated with the management of deer populations and habitat for the maximum benefit of deer hunters are evident, particularly within the Upland and Piedmont Sections of New York and Pennsylvania and the Piedmont Section of New Jersey. A resumé of these problems follows.

(1) In portions of the Upland Section in Pennsylvania, and to a lesser extent in New Jersey and New York, habitat carrying capacity is inadequate to support existing year-round deer populations. This condition, varying by location from mild to serious in its effects, has resulted in winter losses of deer to starvation, deterioration of the vegetation through overbrowsing, and deer browse damage both to agricultural crops on farmland and to ornamental and vegetable garden plants in some residential suburbs. In other areas the problem and its effects are not currently significant but threaten to become so within a few years. There appear to be no winter losses due to starvation in the Piedmont Section.

(2) Vegetational succession is a continuing phenomenon in all parts of the species' range, acting to reduce the amount of habitat available. Sub-climax phases of this succession wherein are found a predominance of shrubs, together with trees of seedling, sapling, and advanced reproduction sizes, are the most favorable stages for providing deer with natural woody foods and cover in fair to excellent abundance. The favorable vegetation size-classes of these phases are associated most extensively with agricultural land reverting to shrubs and young trees and to young second-growth hardwood and coniferous farm woodlands and forests which have become established on many areas following logging operations. With the passage of time these earlier phases yield gradually to larger-sized maturing tree growth, beyond the physical reach of deer and offering less food and cover for them. On many areas of large aggregate acreage, retirement from production of agricultural lands and reduction or cessation of logging operations on a large scale in the last few decades have resulted in the existing or impending habitat condition in which a preponderance of the vegetation has matured to tree size to the detriment of deer populations.

(3) Another problem, having strong influence on the magnitude of the first one listed above, is underutilization of deer by hunters on areas of imminent and

actual over-population. This problem arises in part from the posting of extensive amounts of land, mostly privately owned, against hunters who are thus prevented from removing surplus animals from such problem areas. Damages occur to agricultural crops, ornamental, and vegetable gardens in farming and suburban residential areas, and vegetative food and cover in wildlife habitat in portions of all 3 sections of the basin. It is also the result of overly-restrictive hunting regulations which prevent adequate harvests of deer. These usually take the form of reliance over prolonged periods of time on bucks-only regulations and on infrequent or inadequate doe or hunters-choice seasons in counties of critical deer overabundance. The difficulty of coping with underutilization of deer caused by land posting is self-evident. The principal obstacles in surmounting this problem in relation to overly-restrictive hunting regulations are (1) the inadequacy or lack of legislative authority for State conservation agencies to establish the degree of liberalized hunting regulation when and where needed, and (2) the inadequacy or lack of support received by these agencies from sportsmen in obtaining and implementing such legislative authority as needed. This problem is most prevalent in the Upland Section of the basin where deer habitat is most abundant.

(4) The posted land situation has another facet which stands independently as a problem of another sort. Through posting, the deer hunting public is deprived of large acreages on which to pursue their sport, including lands on which deer populations are in approximate balance with the range carrying capacity as well as areas on which they are excessively numerous. Posting of land against public hunting is frequently undertaken as a permanent measure or sporadically by private landowners according to whim. On many tracts, hunting by the public is prohibited, being permitted only to a select few friends of the landowner or restricted to members of sportsmen's clubs which have secured tracts for hunting purposes.

Private posted lands are estimated to comprise over 50 percent of the area of the Upland Section, in Pennsylvania and New York especially.

Added emphasis is given to the adverse effect of posting on public hunting opportunity in the Upland by the great importance of this section in furnishing the basin with huntable deer populations.

In the Piedmont and Coastal Plain Sections, the problem is serious also in places. It is more acute in the vicinity of high human population concentrations where entire townships may be closed but is by no means confined to such areas. An estimated 40 percent of private lands in Subbasin No. 12 and 80 percent in Subbasin No. 10 are closed to public hunting. Although public hunting may not be permitted generally over large areas, the fact remains, of course, that limited hunting is carried out by some form of permit on most areas. Pressure on posted land may be fairly heavy, as in New Jersey.

State Parks are a class of public lands frequently closed to deer hunting in the several States despite a recent trend to open more of them. Their acreage is considerably smaller than private posted acreage; nevertheless, the parks are not so small in total area as to be unimportant as potential public hunting areas.

(5) In many portions of the basin within the 3 sections, deer habitat is being reduced in quantity and quality as a result of changes initiating new and detrimental land-use practices. One of the more important of these practices within the Upland Section is extensive coal strip-mining operations, primarily in the upper Lehigh and Schuylkill River drainages. In the Piedmont and Coastal Plain Sections deer habitat is being reduced in acreage and unfavorably altered through industrial development of non-urban land, expansion of urban and suburban residential housing developments, dredging and spoil deposition along rivers in connection with river navigation projects, and intensification of certain modern agricultural practices.

(6) State conservation agencies are often hampered in their efforts to manage the deer resource within their jurisdiction by shortage of funds. The license dollar must usually cover the cost of managing a number of wildlife game species to maintain and increase public hunting opportunity. Frequently, it cannot be stretched to provide enough funds for research to yield solutions for many unsolved deer

ecology and management problems, to improve and manage deer habitat and populations on public lands, or to acquire such lands for public hunting.

Upland Game (Forest Game)

149. Ruffed grouse, wild turkey, woodcock,[9] gray squirrel, varying hare, raccoon, and red and gray foxes are the important upland forest-game species of the Delaware River Basin which are treated in this report.

150. Grouse are distributed throughout the basin, predominantly in and near the wooded cover types, but are less numerous in the Coastal Plain and Piedmont Sections than in the Upland where the best and most abundant ruffed grouse habitat occurs. With the exception of the wild turkey, grouse population densities, even in the best coverts, are considerably less than those of other listed forest game species. This exigency, together with the well-known cyclic trends in population levels, is a natural species characteristic. Grouse hunting is a popular form of outdoor recreation among a small segment of the hunting fraternity, especially in the Upland part of the basin. In terms of annual hunting pressure and harvest, the ruffed grouse ranks second to the last place wild turkey, except in the New York portion of the Upland where its status in these respects is well above the varying hare, raccoon, foxes, woodcock, and the wild turkey. The value of ruffed grouse as a game bird should not, however, be underestimated, despite these estimates.

151. The wild turkey had become extirpated from its former natural range in the Delaware River Basin by the latter part of the 19th century, chiefly through overhunting and an intolerance of far-reaching adverse land-use changes within much of its preferred forest habitat, habitat once nearly removed from human occupancy and influence. Aided by removal of the species from the game list for many decades in all States concerned; by a reversal in many areas of the earlier trend of clearing forest land for agricultural and intensive logging of hardwood forests, which has led to re-establishment of more favorable turkey habitat; and by carefully implemented restocking programs, populations of this excellent game bird are gradually but slowly increasing. This favorable situation is occurring largely in the remote parts of the Upland Section in Pennsylvania and New York, where habitat

9/ Woodcock is not ordinarily considered one of the resident upland forest game species. It is treated here for convenience; too little material on it is available to warrant coverage under a separate heading.

conditions are more conducive to successful re-establishment of huntable turkey populations than any other portion of the basin. Pennsylvania is the only State of the Delaware River Basin which has thus far been able to reopen its hunting season on the wild turkey. Notwithstanding the small annual harvest within the Upland portion of this State, the bird is becoming quite popular among increasing numbers of hunters. As populations and hunter success increase, it will undoubtedly become more so. An open season in some future year in New York is indicated at such time as continuing State efforts to build up turkey populations to huntable levels in the Catskill Mountains and vicinity appear to have achieved this goal.

152. Distribution of woodcock in the Delaware River Basin is spotty. Heaviest population densities occur in spring and fall when the birds are found temporarily in the region during their migration between the northern summer breeding and the southern wintering grounds. Small nesting populations are found in localized areas having brushland types and young, open second-growth hardwood and mixed woodland stands. Hunting pressure on woodcock is relatively light compared with most species in the basin. Several thousand birds are bagged each fall, mainly in the Upland Section where habitat is attractive to the migrating populations.

153. Gray squirrels are found in farm woods and forestland in all 3 sections of the basin. The denser populations occur in hardwood stands of oak, hickory, beech, and walnut having adequate numbers of matured, mast-producing trees. Squirrel numbers are probably increasing in many areas where young hardwood stands of these species are approaching maturity. The species ranks in popularity among upland game hunters in the basin second only to the cottontail rabbit. Despite the high hunter interest, squirrel breeding populations could support heavier hunting pressure in most squirrel habitat of the 4 States without reducing the capacity for satisfactory sustained yield. The estimated annual gray squirrel kill in the entire basin if over 100,000 animals; more than 55,000 of these are harvested in the Piedmont Section and over 36,000, in the Upland Section.

154. Varying hares are limited in distribution almost entirely to the Upland Section in New York and Pennsylvania. They are found in forested areas at the higher altitudes largely in mixed stands where cover as well as food is adequate. Populations are very small compared with nearly all other upland game species. Hunting pressure on hares is also comparatively light, the annual harvest amounting to only a few hundred individuals.

155. Raccoons are found in most portions of all physiographic sections of the Delaware River Basin. Their habitat preferences

approximate those of gray squirrels, with the presence of streams and other types of water being an additional determinant of their occurrence. Although the raccoon is pursued for its fur, the bulk of its current increasing popularity - during this period of low fur market prices - is centered on its quality as a game animal. To be sure, its popularity in this region does not approach its popularity as game farther south in the country where raccoon hunting - with hound - reaches levels of enthusiasm bordering on the fanatic among many hunters. Nevertheless, the sport of raccoon hunting is indulged in by thousands of hunters throughout the basin. Rough estimates of the annual harvest place the kill at several thousand animals in each section.

156. Red and gray foxes are also species having the dual status of fur and game animals, besides being considered almost universally as undesirable predators. Foxes are found in all sections and nearly all rural habitat types, from forested to open agricultural. Somewhat greater interest is evinced in both species as game than as fur animals, largely because prices for fox pelts are presently very low. In some areas, such as in Delaware and southeastern Pennsylvania, fox hunting has been very popular among a few hunters since Colonial days, regardless of the status of pelt prices. Only a relatively small proportion of the total number of upland game hunters pursue these species; they do so mostly with hounds. Reliable harvest figures are not available; however, the annual kill in the basin must amount to several thousand. In all probability, the bulk of the kill is accounted for not by confirmed fox hunters but by persons who trap them for bounty payments. Among the States represented in the basin, only Pennsylvania has a bounty on foxes. However, certain counties and townships in New Jersey pay a fox bounty.

157. The management of upland forest game species in the basin involves a number of problems. Most of them occur in the Upland and Piedmont Sections. They are summarized below.

(1) Although quite extensive throughout the basin, ruffed grouse range is presently low in carrying capacity with the result that the grouse population is inadequate to satisfy public hunting pressure. Population densities are consistently low. Even in the Upland Section, where most of the better grouse habitat occurs, prevalence of deer overpopulation and resultant overbrowsing has reduced its quality and probably its quantity. Elsewhere, the limited carrying capacity is due to adverse land-use practices.

(2) Populations of wild turkey are also inadequate to meet hunter demands, but the problem apparently is not caused by a lack of suitable range with adequate carrying capacity, but results from the fact that wild turkey were once extirpated and the job of re-establishment has been a slow process and costly.

(3) There is a shortage of upland forest game habitat open to public hunting. State-owned and managed lands open to public hunting do not begin to meet this demand. Aggravating the open-land shortage is the policy of prohibiting hunting on most State park lands. The problem is evident in the 3 sections of the basin though it is understandably more acute in the Piedmont and Coastal Plain Sections of Pennsylvania and New Jersey. Human populations are heavier in these sections than in the Upland; hunting land shortages are most severe in the vicinity of urban areas.

(4) Funds available to most State wildlife agencies are generally inadequate to acquire additional lands for public hunting, or to manage them, if acquired, to increase huntable upland forest game populations.

Upland Game (Farm Game)

158. Upland farm-game species of sufficient importance to warrant treatment in this report are the cottontail rabbit, ring-necked pheasant, bobwhite quail, and woodchuck.

159. Rabbits are found in most cover types of all sections, though they are, of course, more abundant within actively farmed and reverting, brushy lands of agricultural areas. Cottontail rabbit habitat in the Piedmont Section would appear to support more rabbits per unit area and/or be more extensive than in the other 2, with the Upland second in importance in these respects. The species ranks among the most popular, perhaps first in popularity, in the basin in terms of the number of hunters interested in rabbit hunting; it definitely ranks first in numbers killed annually during hunting season. Rough annual minimal estimates suggest the harvest in the Upland Section to be in excess of 100,000, and, in the Piedmont, in excess of 150,000. Coastal Plain kill estimates are lacking. The bulk of the estimated harvest is attributed to the Pennsylvania portion of each section. Natural populations, rather than pen-reared animals, account for much the larger portion of the total basin-wide kill.

160. Rabbit stocking is undertaken in New Jersey on a small scale and in Pennsylvania on a considerably larger scale. A live

trapping-transfer program has been in operation in the latter State for several years. Native rabbits are trapped in areas closed to hunting and in locations such as orchards and urban outskirts, where they have become destructive of fruit trees, other vegetation and garden crops. The trapped rabbits are transplanted to open hunting areas where they are not currently overabundant or destructive.

161. Although natural ring-necked pheasant populations are found in the 3 sections of the basin, the richer agricultural lands of the Piedmont in Pennsylvania and New Jersey support most of the heavier populations. The Coastal Plain is second and the Upland Section a poor third in importance. The best pheasant habitat in the basin ranks among the best in eastern United States. Resident and non-resident hunter interest in this game bird is high, preference for the pheasant exceeding that for the cottontail in the best pheasant habitat areas despite the larger total kill of rabbits in these areas. Such areas include the Piedmont portions of the Schuylkill, Tohickon-Neshaminy, and Brandywine Subbasins in Pennsylvania, where more than 55,000 birds are killed annually, and the Paulins Kill-Musconetcong and Crosswicks-Rancocas Subbasins of New Jersey.

162. Because hunting pressure far exceeds the annual harvestable surplus in nearly all parts of the pheasant range of the Delaware River Basin, the 4 State wildlife agencies stock artificially-reared birds to help narrow the differential between the supply and demand for harvestable birds. Pennsylvania is first and New Jersey second in number of birds stocked, several thousand being liberated each year in these States. Both hunting pressure and the number of stocked birds in the New York portion of the basin is low since this area is marginal pheasant range.

163. Quail populations in the basin are the smallest of the upland farm-game species. They are largest in the Coastal Plain Section, somewhat smaller in the definitely marginal quail habitat of the Piedmont, and insignificant in the Upland Section. Hunter interest in quail is fairly high in the Coastal Plain portions of New Jersey and Delaware; in the Pennsauken-Raccoon Subbasin, for example, it appears to be first in popularity as an upland game bird. Annual kill figures for the basin are not available but several thousand birds are undoubtedly harvested, primarily in the southern third of the basin. Stocking of artificially-reared birds to augment huntable natural populations is carried out each year, mostly in New Jersey and Pennsylvania, but the stocking programs are on a somewhat smaller scale than those undertaken for pheasants.

164. Woodchucks occur throughout the basin, though they are more abundant in agricultural than woodland areas. Little is known about woodchuck population densities. Its popularity among upland

game hunters is probably higher than might be expected since it is overshadowed by all other species covered in this report. Seldom is it treated with as much interest as is afforded other species in sporting magazines, outdoor newspaper columns, and in hunting circles generally. Thousands are killed annually in all States of the basin, frequently as part of a voluntary, unofficial "vermin" reduction program on farmlands. As many sportsmen know, woodchucks frequently have much greater positive value as farm wildlife than negative value as cropland foragers and burrowers.

165. As in the case of upland forest game, problems in the management of farm game beset State agencies charged with the welfare of these species. The principal problems are outlined below.

(1) Within the Upland portions of New York and Pennsylvania, a long term trend of diminishing agricultural activity in terms of acreages actively farmed in some areas may, over a period of years, cause a concomitant reduction in typical cottontail rabbit habitat, as abandoned fields revert to shrub and subsequently to woodland cover types. Huntable rabbit population levels may be expected to decline under these circumstances as forest land acreage increases at the expense of open agricultural lands.

(2) Where deer overpopulation has reached a level at which numerous deer are forced to forage on farmland pasture and crop fields, rabbit forage is correspondingly reduced by this species competition. This problem, while not wide-spread, occurs on some farmed areas of the Upland Section in Pennsylvania and New York.

(3) Natural environmental conditions (including food and cover and favorable climatic factors, especially in winter) do not permit levels of productivity and survival sufficient to yield huntable fall pheasant populations to meet hunter demand. This applies in nearly all portions of the range, from marginal to best. As a result, costly programs of stocking artificially-reared birds by State conservation agencies are undertaken in the attempt, only partially successful, to bridge the gap between supply and demand.

(4) Problem No. 3 is applicable also to quail, especially in the Piedmont Section of Pennsylvania and the upper Coastal Plain Section.

(5) Improvement in the efficiency of agricultural methods on the land during the last several decades has increased greatly the total acreage subjected to so-called clean farming, which has reduced or nearly eliminated farm game food and cover from lands so managed; i.e., by elimination of fence balks and hedgerows, by filling sloughs and swales, by green stubble burning, fall plowing, and night hay mowing, to name a few practices. These practices have frequently affected wildlife habitat adversely in quality, as well. Coupled with these practices is the ever present problem of soil erosion which also causes deterioration in the quality and quantity of farm game habitat.

(6) Land-use practices also have another extremely detrimental effect on wildlife, and particularly on farm game habitat--physical elimination of habitat. Extensive expansion of industrial enterprises and residential housing developments beyond urban limits into rural areas are the chief causes of this problem. These activities have been accelerated greatly since the beginning of World War II and have progressed geographically in ever-widening arcs beyond innumberable population centers in the basin; thus far, the effects of these practices have been most apparent in the Piedmont and Coastal Plain Sections.

(7) Reduction in public hunting opportunities on private lands through posting is as serious a problem to farm game as to deer hunters. The treatment of this posting problem as covered previously under Big Game (deer) applies equally to farm game. Existing publicly-owned lands suitable for and open to public hunting of farm game are inadequate to compensate for the loss of such lands through posting, especially in the Piedmont and Coastal Plain portions of the basin.

(8) Insufficient funds available to State conservation agencies for research to solve management problems, to improve and manage habitat and populations, and to acquire lands for public hunting is a problem as important in farm game as in deer management. (See problem No. 6 - Big Game).

Fur Animals

166. The species of this group treated in this report are the muskrat, beaver, mink, otter, skunk, weasel, raccoon, and red and gray foxes. The first 4 listed are considered aquatic or semi-aquatic fur animals and the balance of the species, terrestrial, though the raccoon also frequents aquatic habitat types.

167. The muskrat is found in all States and sections of the Delaware River Basin. Its habitats in order of importance are the estuarine marshes; tidal guts; inland fresh marshes and swamps; lakes, ponds, rivers, and streams of the basin. The species far exceeds in abundance any of the other aquatic fur animals. The habitat types in which aquatic fur animals are found, and their classified relative importance in terms of productivity, are presented in tables 9 and 10. This information is provided for the various subbasins in table 9, and, by estimation, for the 3 physiographic sections, in table 10. Class I, Class II, and Class III aquatic fur animal habitat were established, based upon productivity only, in order of decreasing importance. It is apparent in these tables, that muskrat productivity is highest in the Coastal Plain, followed by the Upland and Piedmont Sections in that order, by virtue of the amounts of the prime habitat, wetlands, in these sections. The sections rank in reverse order for the habitat types of lesser importance - lakes and ponds, rivers and streams.

168. In terms of pelts sold, the muskrat ranks first in commercial importance by a wide margin among all fur animals of the basin. Data on the annual muskrat pelt harvest within the basin and its subdivisions are so fragmentary that a reliable total harvest figure cannot be given here; a rough estimate would be several hundred thousand pelts annually, with the relative importance of the 12 subbasins and 3 sections of the basin as contributors to the total indicated in tables 9 and 10. The species is the only fur animal in the basin having sufficient importance commercially to justify concerted management effort within natural habitat areas. For example, in many of the estuarine marshes of Delaware and New Jersey, tracts of considerable size are managed by their owners or lessees for muskrat pelt production, principally through the medium of water level control by dikes and gates. In most portions of the basin, however, annual pelt production depends to a large extent on fur prices, and to a lesser extent on food conditions within local habitat units. For the last few years, the number of muskrats trapped has declined to a low level because of low public demand for furs and consequent low prices paid for pelts. Underutilization of this valuable species, as well as other fur animal resources, has resulted from this situation.

169. Beavers inhabit fresh water aquatic habitat types, notably inland marshes, streams, ponds, and lake borders. The Upland Section, which contains a large number and acreage of these types, supports a wider distribution and larger total population of the species than either the Piedmont Section, which ranks second, or the Coastal Plain, which ranks a low third in this respect. Whereas the muskrat requires herbaceous vegetation to meet most of its food requirements, the beaver subsists mostly on deciduous woody vegetation, which is in greater abundance in the

Table 9.--Classification of aquatic fur animal habitat - Delaware River Basin

Subbasin	Wetlands (acres)			Lakes and Ponds (acres)			Rivers and Streams (miles)		
	Class I	Class II	Class III	Class I	Class II	Class III	Class I	Class II	Class III
1-2	2,000+	-	-	-	2,200+ 1/	-	260	161	126
3-4	2,440	7,770	7,060	1,800+	6,500+	7,500+	398	217	445
5	-	8,194	3,093	59	427	3,308	178	142	515
6	-	-	-	-	280	5,700	-	2	70
7	-	-	-	1,210	-	678	92	63	679
8	-	50	150	-	-	-	28	26	240
9	460	856	-	-	-	240	-	-	200
10	-	-	-	85	65	700	32	43	440
11	-	-	-	-	388	126	-	-	85
12	33,500	55,500	-	91	438	1,825	-	50	165
13	43,430	33,870	21,480	-	-	2,000	-	-	56
Total	81,830+	106,240	31,783	3,245+	10,298+	22,077+	988	704	3,021

1/ The sizes of a number of lakes, ponds, and wetlands included in the survey were not available. The " " sign following acreage entries indicates minimum figures.

Table 10.--Classification of aquatic fur animal habitat by sections

Physiographic Section	Wetlands (acres)			Lakes and Ponds (acres)			Rivers and Streams (miles)		
	Class I	Class II	Class III	Class I	Class II	Class III	Class I	Class II	Class III
UPLAND									
1-2	2,000+	-	-	-	2,200+	2,200+	260	261	126
3-4	2,440	7,770	7,060	1,800+2/	6,500+	7,500+	398	217	445
5	-	4,859	1,834	35	253	1,962	106	84	305
7	-	-	-	261	-	146	20	14	147
Total 1/	4,440+	12,629	8,894	2,096+	8,953+	9,608+	775	476	1,023
PIEDMONT									
5	-	3,335	1,259	24	174	1,346	72	58	210
6	-	-	-	-	280	5,700	-	2	70
7	-	-	-	949	-	532	72	49	532
8	-	42	127	-	-	-	24	22	203
9	146	272	-	-	-	76	-	-	64
10	-	-	-	82	63	674	31	41	424
Total 1/	146	3,649	1,386	1,055	517	6,328	199	172	1,503
COASTAL PLAIN									
8	-	8	23	-	-	-	4	4	37
9	314	584	-	-	-	164	-	-	136
10	-	-	-	3	2	26	1	2	16
11	-	-	-	-	388	126	-	-	85
12	33,500	55,500	-	91	438	1,825	-	50	165
13	43,430	33,870	21,480	-	-	2,000	-	-	56
Total	77,244	89,962	21,503	94	828	4,141	5	56	495
GRAND TOTAL 1/	81,830+	106,240	31,783	3,245+	10,298+	22,077+	988	704	3,021

1/ Totals were obtained from cumulative subbasin totals derived from original survey. Physiographic section totals are approximations derived from: (a) arbitrary prorated figures for subbasins in more than one section based on percentage of subbasin area in each section; and (b) figures from subbasins wholly within sections.

2/ See Footnote No. 1, table 9.

aquatic habitat situations of the Upland and Piedmont areas than in the estuarine marshes of the Coastal Plain Section. Occasionally in rural areas, as well as in the vicinity of small human population centers, beavers cause damage by damming and flooding watercourses, in which cases they are usually trapped and transplanted to more remote sites by State game agencies.

170. Beaver population size and density, in local habitat situations and in the sections of the basin, are fairly small compared with the muskrat. The species was once nearly extirpated from many parts of the basin, particularly in the Piedmont Section, but its numbers have increased greatly under the stimulus of State-controlled closed seasons and regulated harvests. The basinwide population probably amounts to a very few thousand individuals.

171. Annual fur harvest data is lacking or fragmentary in most subbasins. Fewer than a thousand pelts appear to be harvested in the basin each year, primarily in the Pennsylvania and New York portions of the Upland, and to a lesser extent, in the Piedmont Section of Pennsylvania and New Jersey. Pelt prices and trapper interest are currently at a low level.

172. Minks and otters are associated with the same habitat situations as beavers and, to a lesser extent, with salt water marshes. Otters are much scarcer in most of these types than minks though both species are represented by small populations. They are probably more widely distributed and more abundant in the Upland and Piedmont Sections than the Coastal Plain. Few annual harvest records are available. Mink pelt sales in the basin amount to a few thousand; otter pelt sales may be fewer than 100. Populations of both species, especially the otter, were undoubtedly higher several decades ago before civilization had usurped so much favored habitat. Pelt harvests were certainly higher in years past when fur prices were higher.

173. Skunks and weasels are fairly well distributed throughout the basin, chiefly in agricultural areas. Little is known about their population densities where they are found; both are rather furtive in their habits and are seldom seen, though skunks are observed more frequently than weasels. Both species rank low in commercial importance as fur sources. As with other species, fur prices are inordinately low and trapper interest in them is presently negligible, except perhaps as subjects for destruction for predatory tendencies in the vicinity of chicken yards.

174. Little need be added here to the comments on the raccoon and red and gray foxes in the Upland Game Section of this report. Only their comparatively low rank as fur animals, as a result of a currently insufficient demand for their pelts in the fur market, bears restatement at this point.

175. The problems attendant to the management of fur animal resources of the Delaware River Basin may be stated briefly as follows:

(1) Destruction of habitat over the years and deterioration in the quality of remaining habitat, particularly for the aquatic fur animal species, is a continuing problem. This is largely the result of the advance of civilization and the attendant alteration or conversion of habitat to land uses less suitable or incompatible to healthy, adequate populations of these species. Marsh destruction and drainage, development of recreational and housing facilities on lakes and ponds, channelization of streams, removal of food and cover vegetation from stream banks, and stream pollution are some of the causes of this habitat destruction and deterioration.

(2) Low pelt prices for fur species for a number of years have discouraged adequate utilization of these resources and have caused economic hardship on many people who customarily derived all or part of their incomes from fur trapping. Because of its prime position as a fur animal, the muskrat is the principal species affected in this manner. A secondary problem arising from this situation is the difficulty of practicing good habitat management on the marshlands where the species is found in numbers feasible for management. Maintaining a balance between muskrat populations and habitat carrying capacities to avoid serious damage to the vegetation by overpopulation is difficult where the stimulus of fair market prices to encourage trapping is lacking.

<u>Waterfowl</u>

176. The Delaware River Basin has highly significant waterfowl value from 2 separate but related standpoints: (a) it provides habitat needed by waterfowl species to fulfill their biological requirements; (b) it furnishes, in these same areas, sites in which basin residents and visitors may enjoy the recreational values of these species, including hunting. The basin waterfowl habitat, in the form of estuarine marshes; tidal guts; inland fresh water marshes and swamps; bays, lakes, ponds, rivers, and streams provides important resting, feeding, and wintering areas for large numbers and many species of migrants and resident breeders, as well as nesting areas for the latter. These birds include many species of ducks, geese, and shore birds. The migrants among them use these areas of the basin seasonally, spring and fall, as well as many other areas of the arctic and subarctic

and east coastal portions of North America, from Alaska to Greenland to the Gulf of Mexico, and even South America.

177. In a survey undertaken as part of this basin-wide study, the waterfowl resources of the basin have been inventoried in terms of quality of habitat and degree of utilization by hunters. Based upon quality of habitat and/or degree of utilization by hunters, 3 orders of importance were established, namely Class I, Class II, and Class III, with Class I being of highest value. Those of lesser importance than Class III, or of unknown value, were not classified. These data have been compiled for the several subbasins in table 11 and regrouped in table 12 by the 3 physiographic sections - Upland, Piedmont, and Coastal Plain, as accurately as possible at this time. Figure 5 is a map of the basin displaying the streams, lakes, ponds, and wetlands which have been classified as waterfowl habitat.

178. Within the Coastal Plain portion of the basin, primarily in the lower Delaware River and Bay, and the scores of thousands of bordering estuarine marshlands and included waters, are found some of the prime resting and feeding units of migrating waterfowl in the Atlantic Flyway, where hundreds of thousands of waterfowl of many species stop off each spring and fall. These areas also furnish wintering habitat for many thousands of ducks and geese and nesting habitat for lesser but significant numbers of dabbling ducks every year. Non-tidal marshes and waters of this section also provide nesting, resting, and wintering sites important to waterfowl, but these are of comparatively less significance than the estuarine areas.

179. Human recreational use of these waterfowl species by hunters and birdwatching enthusiasts is high in the Coastal Plain and is considerably higher in this section than in either or both of the other 2. This is a normal consequence of the pre-eminence of this section, among the three, in total quantity of existing waterfowl habitat.

180. As suggested in table 12, the amount of waterfowl habitat available in the Piedmont is very limited, being in smaller quantity than in either of the other sections. The small amount of good habitat is utilized heavily, however, by migrating waterfowl. The areas are also used to some extent by nesting black ducks and wood ducks, mallards, and blue-winged teal. On the few areas of small acreage accessible and open to public use, waterfowl receive heavy hunting pressure.

181. Somewhat more waterfowl habitat exists in the Upland Section than in the Piedmont portion of the basin, but it still ranks a poor second to the Coastal Plain Section in this respect (table 12). The limited quantity and quality of waterfowl habitat

Table 11.--Classification of waterfowl resources - Delaware River Basin

Sub-basin	Wetlands (acres)			Lakes, Ponds, Bays & Major Streams (acres)			Rivers and Streams (miles)		
	Class I	Class II	Class III	Class I	Class II	Class III	Class I	Class II	Class III
1-2	2,000+ 1/	-	-	5,100-	7,410-	2,400	224	-	-
3-4	1,630	5,880	7,400	1,200-	8,250-	815-	159	235	815
5	-	9,422	1,500	910	2,353	469	31	71	618
6	-	-	-	380	5,785	-	40	16	-
7	-	-	-	1,317	-	570	66	41	828
8	240	-	-	75	488	-	11	36	246
9	2,000	-	-	-	27	216	3	53	286
10	-	350	-	940	95	-	21	98	370
11	7,500	-	-	20,350	47	117	-	42	113
12	54,000	37,000	1,000	37,068	29,618	1,550	14	25	260
13	67,571	30,343	7,289	64,000	8,000	-	-	110	74
TOTAL	134,941+	82,995	17,189	131,340-	62,073-	6,137-	569	727	3,610

1/ See Footnote No. 1, table 9.

Table 12.--Classification of waterfowl resources by sections

Physiographic Section	Wetlands (acres)			Lakes, Ponds, Bays, and Major Streams (acres)			Rivers and Streams (miles)		
	Class I	Class II	Class III	Class I	Class II	Class III	Class I	Class II	Class III
UPLAND									
1-2	2,000+ 2/	-	-	5,100+	7,410+	2,400+	224	-	-
3-4	1,630	5,880	7,400	1,200+	8,250+	815+	159	235	815
5	-	5,587	890	540	1,395	278	18	42	366
7	-	-	-	284	-	123	14	9	179
Total 1/	3,630+	11,467	8,290	7,124+	17,055+	3,616+	415	286	1,360
PIEDMONT									
5	-	3,835	610	370	958	191	13	29	252
6	-	-	-	380	5,785	-	40	16	-
7	-	-	-	1,033	-	447	52	32	649
8	203	-	-	64	413	-	9	30	208
9	636	-	-	-	9	69	1	17	91
10	-	337	-	905	91	-	20	94	356
Total	839	4,172	610	2,752	7,256	707	135	218	1,556
COASTAL PLAIN									
8	37	-	-	11	75	-	2	6	38
9	1,364	-	-	-	18	147	2	36	195
10	-	13	-	35	4	-	1	4	14
11	7,500	-	-	20,350	47	117	-	42	113
12	54,000	37,000	1,000	37,068	29,618	1,550	14	25	260
13	67,571	30,343	7,289	64,000	8,000	-	-	110	74
Total	130,472	67,356	8,289	121,464	37,762	1,814	19	223	694
GRAND TOTAL 1/	134,941+	82,995	17,189	131,340+	62,073+	6,137+	569	727	3,610

Footnotes: 1/ See Footnote No. 1, table 10

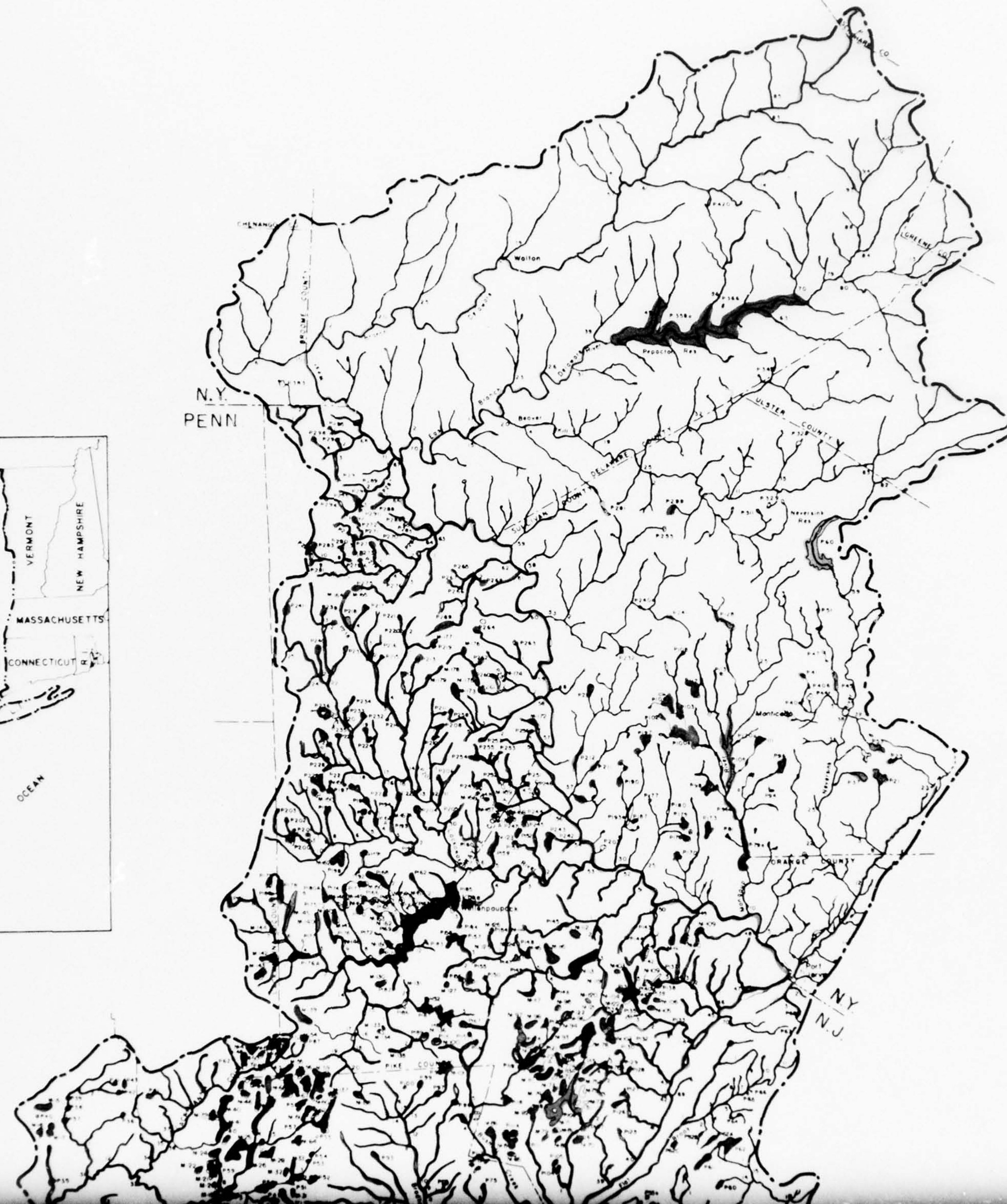
2/ See Footnote No. 1, table 9

in the Upland portion provides resting and feeding areas for migrant birds as well as some nesting territory for dabbling ducks. As in the Piedmont Section, hunting opportunity is understandably limited much more severely than in the Coastal Plain region of the basin.

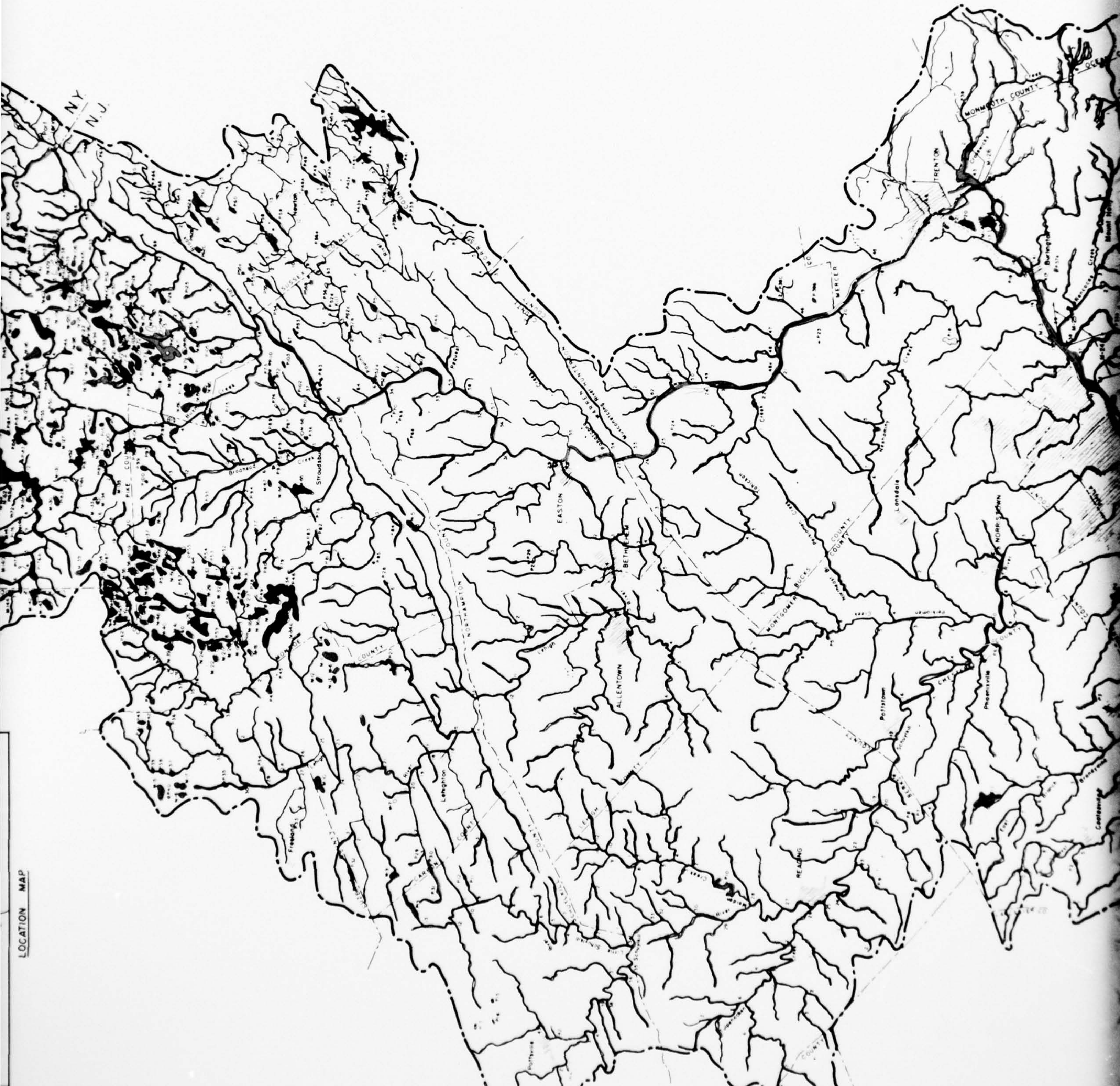
182. The status of the waterfowl resource of the Delaware River Basin leaves much to be desired from the standpoint of the welfare of the waterfowl species themselves and, ultimately, the human utilization of them. The principal weaknesses in the condition and utilization of the resource are pointed out below:

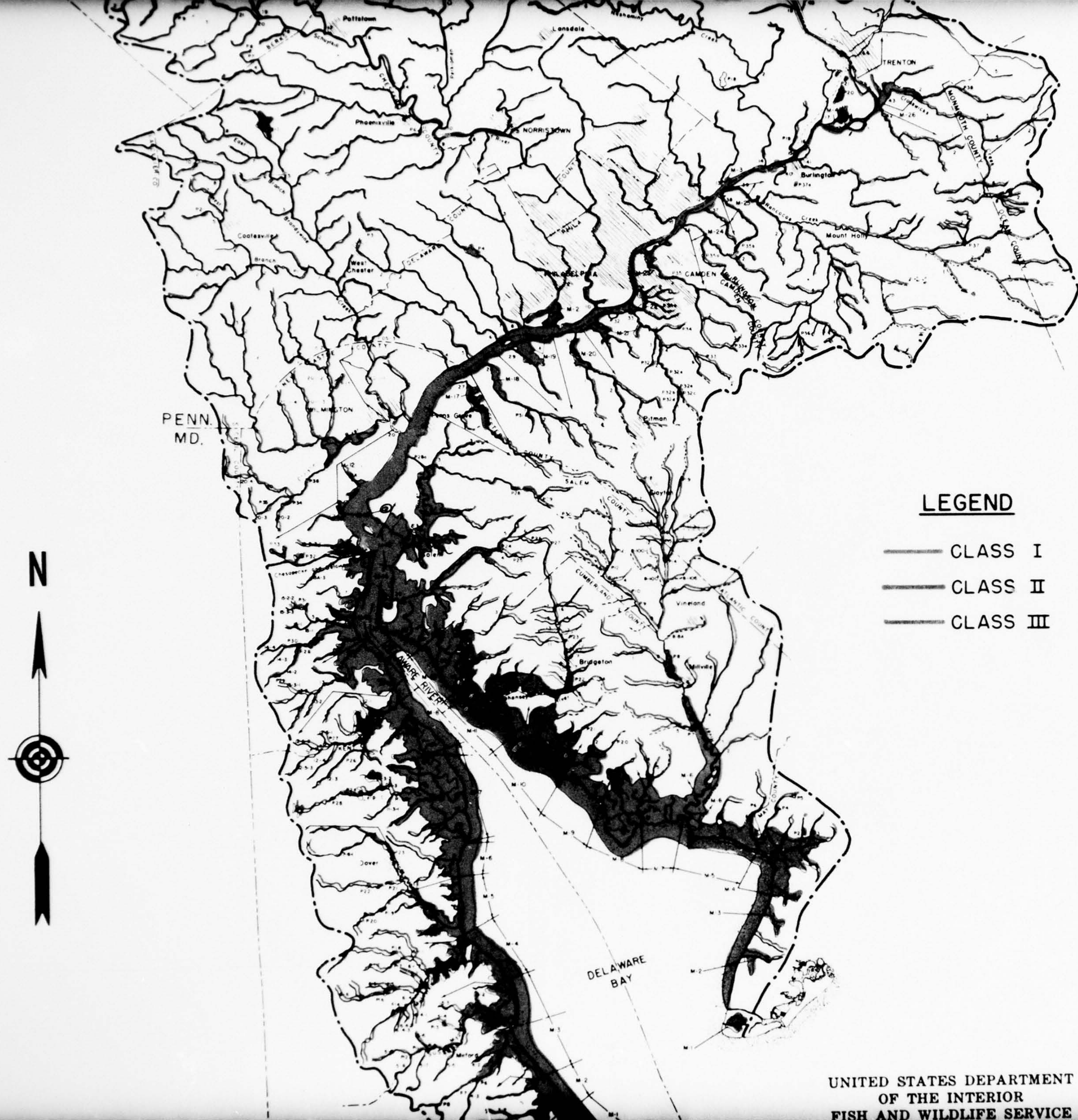
(1) Wetland habitat upon which waterfowl have undisputed dependence as resting and feeding areas throughout the year, and especially during spring and fall migrations, and upon which they depend as breeding areas to a lesser extent, is being destroyed or unfavorably altered at a rapid and accelerating rate in many vital areas of the basin. Salt and fresh water marshlands are the principal types of wetland habitat affected. Man, as usual, is the principal agent of such destruction and alteration through the media of adverse land-use practices. These practices include: filling --for purpose of spoil disposal from river and bay navigation improvement projects, for industrial plant construction, for residential and other community development, for refuse disposal, from deposition of soil transported by water from upstream erosion projects for no positive reason; drainage and/or diking for mosquito control and agricultural cropping; application of insecticides for mosquito control; and pollution of wetland waters, for no positive reason. The problem is most acute and widespread geographically in the Coastal Plain Section of New Jersey and Delaware, of second importance in the Piedmont portion of Pennsylvania, and of third and much less importance in the Upland Section. This ranking reflects largely the distribution and abundance of natural wetland habitat within the basin, historically and presently.

(2) Wetland habitat, notably marshes of suitable quality for waterfowl, is in short supply by virtue of regional physiographic conditions in much of the Piedmont, and to a lesser degree in the Upland, Sections of Pennsylvania, New Jersey, and New York. This shortage includes resting and feeding areas for migrating birds, and to some extent, all types of habitat for the fewer numbers of breeding birds in these sections.



LOCATION MAP


N.Y.
N.J.
SUSSEX
MONMOUTH COUNTY
TRENTON
MERCER
Burlington
Stroudsburg
EASTON
BETHLEHEM
ALLENTOWN
NORTHAMPTON
MONTGOMERY
BUCKS
COUNTY
Lansdale
NORRISTOWN
Pottstown
Phoenixville
READING
Lehighton
LOCATION MAP



UNITED STATES DEPARTMENT
OF THE INTERIOR
FISH AND WILDLIFE SERVICE

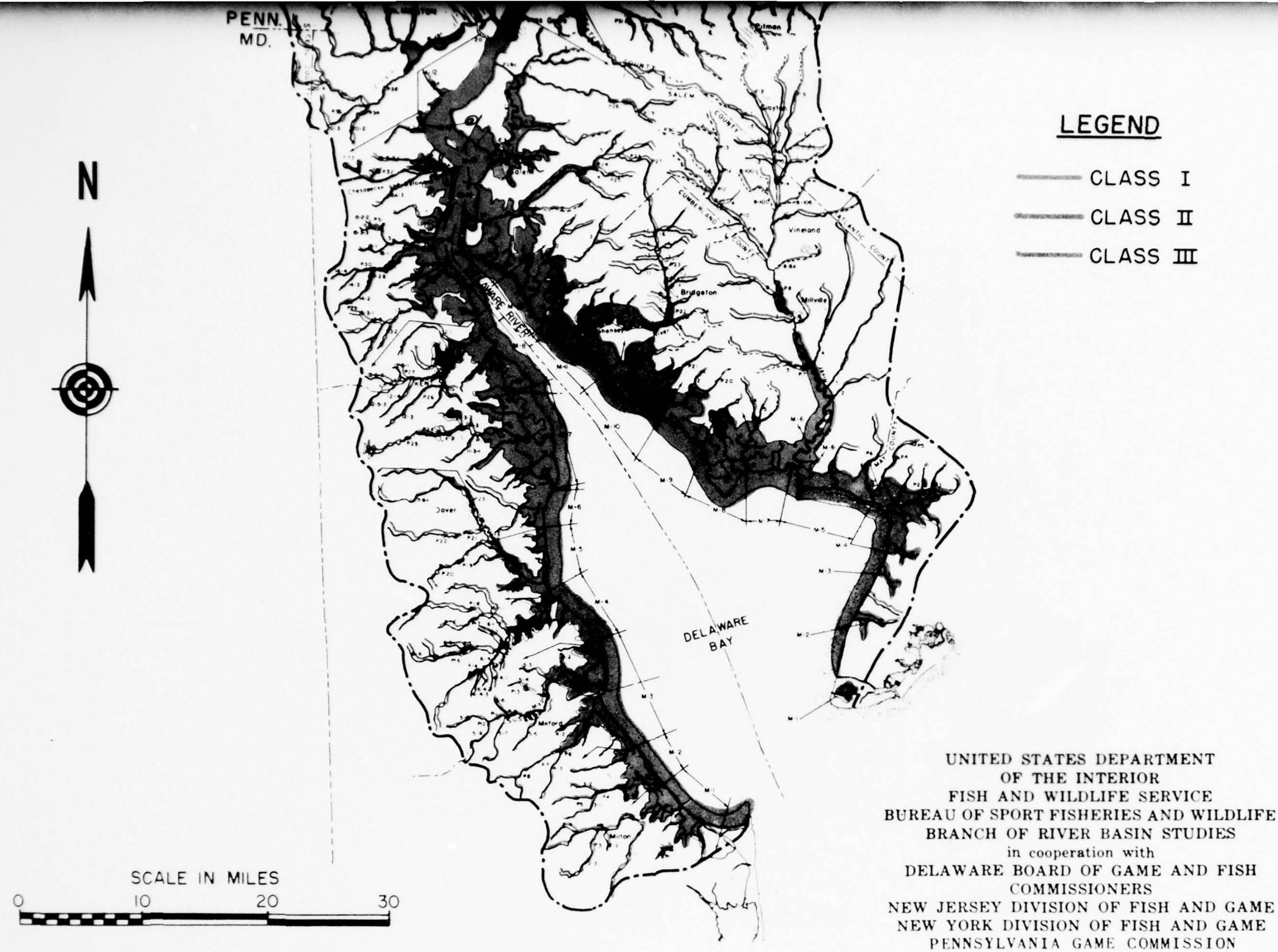


Figure 5. – Waterfowl habitat map Delaware Basin

(3) Public waterfowl hunting opportunity on much privately-owned and on some publicly-owned wetland areas frequented by waterfowl is prevented through posting of such lands against trespass by hunters. This situation is prevalent within all sections of the basin but appears to be more serious on wetlands in the Piedmont and Coastal Plain Sections of Pennsylvania and New Jersey.

(4) Public waterfowl hunting opportunity is limited in some wetland areas on which hunting is permitted through the lack or shortage of public access facilities. Such access problems occur in all sections of the basin. Examples may be found in Subbasins Nos. 5, 6, 7, 11, and 12, including long stretches of the Delaware River and principal tributaries in Pennsylvania and New Jersey, and estuarine marshes in New Jersey.

(5) Public waterfowl hunting opportunity is limited by the small amount of available wetlands of suitable quality to harbor waterfowl in huntable concentrations. This is evident especially in Subbasins Nos. 6 and 7 of the Piedmont Section. This problem is, of course, closely allied to problem No. 2.

(6) The acreage of wetland habitat in public ownership, which is required to better assure current and future biological requirements of waterfowl and, consequently, the realization of recreational values from this resource by the public, is inadequate in the basin.

(7) The general public is not sufficiently aware of the shortsightedness and unfavorable consequences of wetlands destruction and deterioration. There is insufficient awareness of the value of wetlands as habitat for waterfowl, other wildlife, and fish resources, and as land possessing highly significant recreational value to many people. This status of public awareness affects unfavorably the allied problem of replacing destroyed and deteriorated wetland habitat. Such replacement is rapidly becoming either an impossibility because of the diminution of available and suitable wetlands or a very costly proposition in terms of creating substitutes for natural wetlands, depending on the locality involved.

With-The-Project

Big Game

183. Table 13 summarizes briefly in acres the effect on deer habitat of operating the 19 Major Water Impounding Reservoirs proposed for construction in the Delaware River Basin. The acreage to be destroyed consists of the aggregate area of lands below the several maximum operating pool levels and the acreage to be altered unfavorably in quality and quantity is comprised of an additional aggregate area within the flood control pools of these projects. The acreages presented in this and subsequent tables are, of course, preliminary estimates. They will be refined to account for such existing non-wildlife land uses as roads, urban areas, etc., when this information may become available and when detailed studies of the individual projects are completed.

184. (Shohola Falls has apparently been eliminated as one of the final MWI projects): Since the quantity and quality of wildlife populations are bound inextricably with the habitat in which they must live, numerical estimates of losses to these resources associated with proposed reservoir construction is expressed, in text and table herein, in terms of acreage of land lost. When detailed consideration of authorized reservoir projects becomes possible, expresssion of these losses in other, additional terms will be undertaken, and factors compensating for estimated losses will also be discussed. Nevertheless, owing to the extreme difficulty of measuring accurately and meaningfully wildlife losses in terms of population numbers as well as the impossibility of dissociating wildlife populations from their habitat requirements, loss estimates expressed in acres of land must continue to be a primary yardstick of measurement.

Upland Game

185. The effect of operating the 19 Major Water Impounding Reservoirs proposed for construction in the Delaware River Basin on forest game, including woodcock, are summarized briefly in table 14; and on farm game, in table 15.

186. Two proposed reservoirs would inundate portions of State-owned lands managed for or planned for managing upland game species. The Shohola Falls project, already cited under Big Game, would affect forest game primarily on the Pennsylvania Game Commission's recently acquired and soon to be developed tract. The Tocks Island Reservoir would inundate approximately 260 acres of a public shooting grounds owned and managed by the New Jersey Division of Fish and Game. This tract is located in the Flat Brook Valley. Habitat developed for farm game and public use and management facilities, including buildings and parking lots, would be affected.

Table 13.--Effect of operating proposed main stream reservoirs on deer habitat in the Delaware River Basin

Phase & State	Habitat to be destroyed (acres)				Habitat to be unfavorably altered (acres)			
	Upland	Piedmont	Coastal Plain	Total	Upland	Piedmont	Coastal Plain	Total
Phase I								
N. Y.	6,100	-	-	6,100	-	-	-	-
Pa.	8,160	-	-	8,160	3,000	-	-	3,000
N. J.	1,500	-	-	1,500	350	-	-	350
Del.	-	-	-	-	-	-	-	-
Total	15,760	-	-	15,760	3,350	-	-	3,350
Phase II								
N. Y.	4,200	-	-	4,200	-	-	-	-
Pa.	3,245	-	-	3,245	830	-	-	830
N. J.	-	3,970	-	3,970	-	-	-	-
Del.	-	660	2,900	3,560	-	-	-	-
Total	7,445	4,630	2,900	14,975	830	-	-	830
TOTAL PHASES I & II	23,205	4,630	2,900	30,735	4,180	-	-	4,180

Table 14.--Effects of main stream reservoirs on upland forest game species

Phase & State	Habitat to be destroyed (acres)				Habitat to be unfavorably alt. (acres)			
	U	P	C-P	Total	U	P	C-P	Total
Phase I								
N. Y.	6,100	-	-	6,100	-	-	-	-
Pa.	7,550	-	-	7,550	3,000	-	-	3,000
N. J.	-	-	-	-	-	-	-	-
Del.	-	-	-	-	-	-	-	-
Total	13,650	-	-	13,650	3,000	-	-	3,000
Phase II								
N. Y.	4,200	-	-	4,200	-	-	-	-
Pa.	3,245	-	-	3,245	830	-	-	830
N. J.	-	-	-	-	-	-	-	-
Del.	-	-	-	-	-	-	-	-
Total	7,445	-	-	7,445	830	-	-	830
TOTAL PHASES I & II	21,095	-	-	21,095	3,830	-	-	3,830

Table 15.--Effects of main stream reservoirs on upland farm game species

Phase I & State	Habitat to be destroyed (acres)				Habitat to be unfavorably alt. (acres)			
	U	P	C-P	Total	U	P	C-P	Total
Phase I								
N. Y.	6,100	-	-	6,100	-	-	-	-
Pa.	4,160	2,350	-	6,510	1,720	1,100	-	2,820
N. J.	1,500	-	-	1,500	350	-	-	350
Del.	-	-	-	-	-	-	-	-
Total	11,760	2,350	-	14,110	2,070	1,100	-	3,170
Phase II								
N. Y.	-	-	-	-	-	-	-	-
Pa.	1,725	9,320	-	11,045	830	3,010	-	3,840
N. J.	-	5,530	-	5,530	-	-	-	-
Del.	-	660	2,900	3,560	-	-	-	-
Total	1,725	15,510	2,900	20,135	830	3,010	-	3,840
TOTAL PHASES I & II	13,485	17,860	2,900	34,245	2,900	4,110	-	7,010

Fur Animals

187. A considerable amount of fur animal habitat, though undeterminable as to extent at this time, will be destroyed and unfavorably altered for these species as a result of constructing the Major Water Impounding Reservoirs in the Delaware River Basin. Most of this habitat in the form of streams, marshland, agricultural and forest land is coincident with the habitat of other species and groups of species covered in this report. The reader is referred to the tabular estimates of destruction and unfavorable alteration in the With-the-Project treatment of the following topics for a rough appraisal of the magnitude of this damage: Fish - cold water and warm water; Wildlife - waterfowl, forest game, and farm game.

188. One known specific instance of destruction of and unfavorable alteration in fur animal habitat on State-owned wildlife land is associated with the construction of the proposed Shohola Falls Reservoir. Several thousand acres of State land within this reservoir site, an appreciable portion of it in wetland acreage and stream mileage, is involved.

Waterfowl

189. M.W.I. Reservoir construction would have a significant effect on the waterfowl resource in the Delaware River Basin. As far as can be determined at present, these project effects would involve only complete habitat destruction, the amount of which is summarized in table 16. The total acreage listed in this table under Pennsylvania (Upland), Phase I, includes approximately 1,200 acres of affected waterfowl habitat in the tract recently acquired by the Pennsylvania Game Commission at the Shohola Falls site.

Table 16.--Effects of main stream reservoirs on waterfowl habitat

Phase & State	Habitat Destroyed (acres) 1/			
	U	P	C	Total
Phase I				
N. Y.	2,500.0	.0	.0	2,500.0
Pa.	1,150.0	.0	.0	1,150.0
N. J.	.0	.0	.0	.0
Del.	.0	.0	.0	.0
Total	3,650.0	.0	.0	3,650.0
Phase II				
N. Y.	.0	.0	.0	.0
Pa.	.0	33.0	.0	33.0
N. J.	.0	430.0	.0	430.0
Del.	.0	.0	5.0	5.0
Total	.0	463.0	5.0	468.0
TOTAL PHASES I & II	3,650.0	463.0	5.0	4,118.0

1/ (Includes only those few specific areas of exceptional value that were readily apparent. Waterfowl habitat occurs in varying degrees of quality and quantity at almost every reservoir site.)

SECTION VI. - DISCUSSION

Fresh-Water Fisheries

Cold-Water Species

190. The cold-water fishery resources of the Delaware Basin are in high demand. Unfortunately there are a variety of different conditions prevalent in each section of the watershed that result in inadequate trout fishing opportunities to supply the recreational needs of the public.

191. In the Upland Section this inadequacy, insofar as stream fisheries are concerned, arises largely because of posting, lack of access facilities, and poor quality habitat. With minor exceptions, opportunities for public trout fishing on lakes and ponds are presently good.

192. Trout fishing conditions can be improved through opening some of the reaches of major trout streams that are presently posted. Streams having potentials for this measure include: The Delaware River upstream from the mouth of the Lackawaxen River in both New York and Pennsylvania; the East and West Branches of the Delaware River, Little Delaware, Mongaup, Tenmile and Neversink Rivers, and East Brook and Basket Creek in New York; Brodhead, Pocono, Paradise, Van Campens, Bushkill, Shohola, Aquachicola, and Mauch Chunk Creeks, and the Lackawaxen and Lehigh Rivers in Pennsylvania.

193. Development or improvement of access facilities on stream segments that are open to fishing will permit better utilization of the areas. As an example, reaches of the Delaware River that currently support trout, and are not posted, would provide much more fishing than now occurs if access roads and parking lots were available.

194. There are opportunities for quality improvements in the basic trout habitat that will supplement public values derived through increasing the number of stream areas available. There is room to improve the natural productivity and/or carrying capacity of some of the best trout streams of the Upland. Corrective methods to counter the unfavorable alteration that has occurred in the past, and in some cases natural habitat shortages, include: construction of headwater dams to augment streamflow, streamside plantings for bank stabilization and shade, removal of undesirable aquatic vegetation, removal of undesirable competitive fish species, and installation of stream improvement devices such as pool and riffle dams, deflectors and fish shelters. In some cases, further applied research must be undertaken on specific stream segments to find most feasible corrective methods.

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195. Further destruction can be prevented by the adoption of good land-use practices on watershed lands which will result in reduced scouring, sedimentation, and bank erosion on trout streams. Destruction can also be lessened by exercising rather rigid control over stream-channel dredging.

196. It is impossible to forecast the rate at which the program suggested above might be implemented in the foreseeable future and, although there are indications that public demand for trout stream fishing opportunities will expand as the basin population increases in coming years, the probable magnitude cannot be predicted with any degree of accuracy. It is almost certain that obtaining the most ideal improvements on some streams will not result in enough natural trout production to support fishing pressures placed upon them. In such cases, stocking with hatchery-reared trout will be necessary. Stocking of greater quantities of fish is not the answer in all cases, however. In fact, it is recognized that ultimately the better streams may have to provide fishing for sport only, with bag limits altered to provide for fewer large fish being withdrawn from the waters. This may not apply in most New Jersey streams where temperature and water flows will not support all these fish during the summer months.

197. Many of the detrimental effects on the trout resource that are associated with strip mining can be avoided. Backfilling and replanting stripped areas and diversion of surface waters will reduce both acid and sediments which have destroyed several trout streams in the headwaters of the Lehigh and Schuylkill Rivers. The formulation and enforcement of laws that absolutely require mine operators to backfill and replant areas that they alter will avoid additional destruction of this type in the future.

198. Impounding streams leaves no opportunity to avoid destruction of existing fishery habitat in reaches inundated. Where public use of the resource is involved, however, these losses can often be mitigated in similar kind through improvement of use facilities and habitat, and perhaps additional stocking, on other trout streams nearby. Many of the potential threats to trout stream resources below dams can be avoided if insured releases are made which maintain proper volumes, temperatures, and dissolved oxygen content. Construction of the Major Water Impounding Reservoirs proposed in the Upland Section of the Delaware Basin will cause outright destruction of 184 miles of trout stream and unfavorably alter an additional 13 miles, all within the reservoir sites. Although the habitat cannot be replaced, the public use aspects of these losses can be offset, in most instances, in the manner noted above. Proper releases below these same M.W.I. projects will protect at least 32 miles of valuable trout stream in the Upland Section.

199. There is no complete solution to the trout resources problems in the Piedmont Section of the basin. Most of the solutions discussed above for the Upland Section apply in this area, but the physical shortage of natural trout habitat, both pond and stream, and high human populations of the Piedmont suggest that supply and demand cannot be balanced unless demand decreases in a major way, which is not likely.

200. Almost all the stream fishery for trout in this area is dependent upon at least supplemental stocking with hatchery-reared fish. Considerable improvement in public trout fishing opportunity can be attained through securing public use rights on all of streams suitable for stocking, providing access facilities thereto, and then stocking them with legal-size fish. Piedmont streams having reaches that may be acceptable for trout stocking include: Ramseyburg and Ebenezer Creeks, and Stony Brook in N. J.; Neshaminy, Pennypack, White Clay, Chester, Ridley, Valley, and Pocopsin Creeks, and Birch, Buch, Nock, and Broad Runs in Pennsylvania.

201. The few ponds, lakes, and reservoirs that are open to public use and support trout in the Piedmont Section are heavily utilized. Opening of currently closed reservoirs which support trout would have major public recreational benefits. The M.W.I. projects proposed in the Piedmont Section will help solve some of the trout resource shortages. Five of the Phase II reservoirs, having a combined surface area of 5,385 acres, are expected to provide habitat suitable for both trout and warm-water species of fish.

202. It is particularly important that destruction of trout resources be avoided in the Piedmont since there is an existing shortage of suitable habitat. The public use values associated with the 90 miles of existing trout stream that will be destroyed or unfavorably altered as the result of inundation associated with M.W.I. project construction planned in the Piedmont Section will be more difficult to offset than will similar losses in the Upland. Every effort must be made to effect mitigation, however, due to the high importance of the resources involved. Downstream effects of the projects in the Piedmont will threaten 20 miles of trout stream, which can be protected through assured releases of proper volume, temperature, and oxygen content. The M.W.I. projects will also destroy a total of 188 acres of trout lakes in New Jersey that are of a quality practically impossible to replace artificially. The public use aspects of these losses can be replaced in part through construction of substitute trout ponds of greater surface area than those lost. New Jersey will also lose an extremely valuable trout rearing station on the Pequest River as the result of M.W.I. construction. The facilities can be partially replaced through special construction below the Pequest dam site in

conjunction with guaranteed special water supply from the project. Trout stream losses from the channelization activities on Paulins Kill in New Jersey which are related to the Small Watershed Project there, can be offset in part through stream improvement devices on the section altered.

203. The paucity of natural trout water in the Coastal Section makes the cold water fishery resource almost entirely dependent upon artificial management. A few streams of the Coastal Section of the basin could conceivably support stocked trout. Deserving of investigation are: Chester and Ridley Creeks in Pennsylvania; and the inland segments of Oldmans, Raccoon, Swedesboro, Mantua, Big Timber, Woodcrest, and Ellisburg Creeks, and Big Lebanon Run in New Jersey. Several New Jersey ponds support trout currently, and it is probable several other ponds in this section would make trout areas with proper reclamation and management.

204. Programs for maintenance and improvement of the cold-water fish resources, as discussed above, will require a disproportionately large segment to the total funds that are normally available for management of inland fishery resources as derived from general license fees. It is appropriate that additional costs of this kind be borne mainly by those sportsmen who would benefit most. The extra funds needed could be obtained via regulations requiring special licensing for trout angling, the individual fees charged to be of sufficient magnitude to produce the total funds necessary to underwrite the extra costs of special trout management.

Warm-water Species

205. Although warm-water fishery resources of the basin often are taken for granted, as compared with expressed interest in trout, they are nonetheless valuable to a major segment of the angling public. Problems related to fulfilling current public demands for warm-water fishing are most serious in densely populated portions of the Piedmont and Coastal Sections. Upward population trends indicate that these problems will grow more serious and those in the Upland Section will increase in the future. There are several possible measures that can be taken to counter or alter prevailing and threatened limiting factors.

206. Public fishing can be improved through securing better use opportunities on existing waters having habitat values for warm-water fishes. Use of some posted private waters can be obtained through agreements incorporating a guaranty against damages and reasonable compensation to the owners. In some instances, where public needs are high and rights to existing waters cannot be procured through agreements with owners, it will be necessary

to obtain waters through acquisition or long-term lease. It would be particularly beneficial to open the few large lakes and reservoirs that exist along the border between the Upland and Piedmont Sections in Pennsylvania to at least limited public fishing use since these areas constitute most of the potential warm-water pond fishing in the vicinity. It is recognized that where these waters are used as public water supply, the purveyor is subject to obtaining a permit from the State health authorities and conforming to State laws establishing the conditions under which municipal water supplies can be opened to general recreational use. It is also recognized that to meet the restrictions established by law and regulations may entail considerable extra expense on the part of the purveyor. Since the opportunity of enjoying fishing and other recreational pursuits is a benefit which would accrue to the general public, it would seem only fair that some equitable formula for cost-sharing this extra expense be worked out between the public and private interests involved.

207. Public use opportunities can be improved materially through development of adequate access facilities on open waters, including parking lots, roads and paths, and boat launching sites. This measure would be valuable along both shores of the Delaware River, on the several large reservoirs open to the public in New York, on Lake Wallenpaupack and Little Twin, Big Twin, Hunters, and Beach Lakes and Rose Pond in Pennsylvania, and wherever lacking on reservoirs and streams that can be opened to public use in the Piedmont and Coastal Sections.

208. There are opportunities for quality improvements on existing waters that would increase the total warm-water fishery available to the public. Some of the measures which would improve pond fisheries include: water level control, removal of undesirable vegetation, and draining or poisoning followed by restocking. Additional research regarding these quality improvements will provide supplemental data valuable in applying the most feasible management practices to specific situations. Improvement measures applicable to stream fisheries are similar to those mentioned previously with reference to trout fisheries, namely, practices leading to reduction of scouring, sedimentation, bank erosion, and acid mine wastes.

209. In addition to the problems which are common to both types of stream fisheries, warm-water fish habitat has been damaged in many areas by various wastes from industrial and municipal sources. There has been significant progress in pollution correction in the various States of the basin in recent years as the result of active cooperative efforts of State and Federal health agencies, municipalities, private industrial concerns, and conservation agencies. Continuation and expansion of these efforts to include more

stream reaches and eventually to develop and adopt suitable uniform water quality standards for all States concerned can result in a considerable gain to fishery resources of several streams and also protect existing stream fisheries from future damages that would otherwise occur.

210. As a supplement to improving public fishing opportunities through providing for better production and utilization on existing streams and ponds, additional pond-type habitat, with corresponding gains to fishermen, can be provided both through creation or rehabilitation of ponds specifically for fishing and as an incidental function of waters impounded for other primary uses. State conservation agencies have found that restoration or enlargement of old impoundments that either have deteriorated, ceased to exist, or can be increased in area offer feasible ways to increase public fishing opportunity. Some of the better potential sites in New Jersey are the numerous defunct cranberry reservoirs that exist in the Coastal Section. The Delaware Board of Game and Fish Commissioners is considering the restoration of 43 impoundments for fishing. Entirely new impoundments can be created which would have warm-water fishery values. In fact, Pennsylvania has found that development of new sites is more satisfactory than restoration of old reservoirs. Recognized possibilities for the creation of new reservoirs include sites on Jacoby, Jordan, and Black Creeks in Pennsylvania and at Cat Swamp and on the Peaslee Public Hunting Area in New Jersey. Numerous other sites near the headwaters of various streams could be developed with public benefits if adequate funds were available.

211. Almost all endeavors which involve impoundment of waters, regardless of the prompting primary purposes, involve possibilities for incidental benefits as pond-type fisheries. Reservoirs and ponds which are normally built in Piedmont and Coastal Sections usually provide habitat acceptable to warm-water fishes. The smaller type ponds associated with general agricultural activities often provide fishery habitat, and many of the silt detention, conservation, and irrigation reservoirs associated with the Soil Bank and Small Watershed programs of the Department of Agriculture can be of value in providing new fishing areas for the public. Larger reservoirs, such as those built for water supply or hydroelectric power purposes, have potentials as fishing areas and the public will be benefited materially if reasonable fishing rights and use facilities are provided on such areas, particularly those built near population centers. The various reservoirs currently planned for comprehensive development of the water resources of the Delaware Basin have potential incidental benefits in that a total of 42,000 surface acres of water will be created which is expected to be of from fair to excellent value as habitat for warm-water fishes.

212. As an unfortunate incongruity the same impoundment projects that create warm-water fishery of the pond type are totally destructive of the existing stream fisheries within reservoir sites, and may destroy, or alter unfavorably, stream fishery values for considerable distances below dam sites as the result of stream flow and water temperature alterations. Impoundments may also inundate existing ponds or lakes that have special values as fisheries. Alterations of streams to pond-types of fishing are not always acceptable to major groups of interested sportsmen.

213. Efforts to effect replacement in kind, or preservation, of stream fisheries are necessary in such instances. Similar to previous measures discussed for trout, most of the public use values related to warm-water fishery resources that will be lost due to M.W.I. project construction can be mitigated or avoided. Stream fisheries destroyed through inundation cannot be replaced but similar fishing opportunities can be provided through improving fish habitat and access to permit greater use on other streams near each of the destructive project sites. Downstream destruction can be minimized if the projects are operated to produce adequate insured minimum flows and proper water temperatures. Most of the existing pond fisheries that will be destroyed can be mitigated, both as to habitat and public use, either through proper operational and public use facility provisions on reservoirs to be constructed if such proves possible, or through creation of special replacement ponds and lakes specifically designed for the type fishery to be lost.

214. Improvement of the warm-water fishery resource through specific management, acquisition, and construction will require more funds than are now available to State fishery agencies. These agencies are putting into effect most of the various measures mentioned at a rate dictated by the amounts of money they have. An apparent method by which more funds could be obtained to finance quicker implementation of the measures would be increases in the fees charged for general fishing licenses.

Marine Fisheries

215. Achieving the maximum possible preservation and potential use of the marine fishery of the Delaware River Estuary rests upon the elimination of many existing deficiencies, the most critical of which may be grouped collectively under the need for understanding more fully the basic facts pertaining to the ecology of the entire estuarine environmental complex. As this need becomes realized sufficiently with respect to its numerous aspects, it will form the basis for attempting to set up more realistic and comprehensive programs of managing the resources involved so they may be utilized more fruitfully for human benefit, commercially and recreationally. Thus, obtaining more of the basic environmental facts will point up, for example, possible solutions of the current problems of oyster and weakfish abundance in the bay. It may well have the salutary effect

of increasing public understanding of the pertinent cause and effect relationships, and consequently, of bolstering the presently inadequate public support in conducting the studies and using the facts effectively in solving the problems. Formulating and implementing effective management programs would not be easy, should needed ecological facts be available, because of conflicts of interest and jurisdiction in managing and using the resources, as expressed by individuals and groups privately at the grass roots level and publicly at the political level in the halls of government. Meanwhile, in our efforts to preserve and improve the marine fishery resources of the estuary for human benefit, we may be guided by adoption of 2 concepts based on known facts: (1) A marked change in salinity-from whatever cause-will change the distribution and kinds of plants and animals in the estuary. (2) Tidal marshes are essential-beyond question-to the fisheries. Thus, we must preserve a realistic balance between tidal marsh preservation and destruction and conduct research to find ways of increasing the contribution of tidal marshes to the productivity of coastal wildlife and fisheries. Attaining the objectives outlined above will obviously require more money and more cooperation among the various fishery interests-public and private, commercial, recreational, and educational-than is available and in effect. With respect to needed funds, some of the sources relating to recreational use of the estuarine resources are: boat registration, saltwater angling license fees, and charges for use of State-owned boat access and launching facilities.

216. Currently recognized problems related to public recreational uses of the marine fisheries can be solved partially prior to availability of the knowledge to be developed from full formulation and implementation of the research programs needed, if necessary funds are obtained, possibly from one or more of the sources listed above. The quality and quantity of public fishing opportunity can be improved through provision of better access facilities to Delaware Bay, both for boat launching and for shore or dock fishing. Although the State of Delaware provides a number of well-located public boat launching areas along Delaware Bay which have benefited boat fishermen materially, the existing facilities will be inadequate to meet future needs, as they are now and will be in New Jersey. Both States lack public shore fishing areas, and although there is a physical shortage of suitable places for this kind of angling, recreational use of blue crabs and several species of finfish can be improved through public acquisition and development of several of the sites that have potentials for this type of use. Recreational enjoyment of the various fishery resources of the bay also can be improved through dissemination of information to the public as to how best to catch various species. Several species of finfish could and would support greater harvest and provide more angling opportunity if information on how, when, and where to fish for them was available to the general public.

Anadromous and Catadromous Fisheries

217. It is doubtful that the anadromous and catadromous fisheries of the basin can be restored completely to their former high levels of abundance and value attained, for example, during the 19th Century. These resources can be benefited in significant proportions, however, through improvement in current water quality conditions and maintenance thereof, and through avoidance of additional physical or temperature barriers, all with particular emphasis on main stream conditions. Continuation and expansion of recent and current programs to improve water qualities, which have resulted in notable improvements in the lower Delaware River and on several major tributaries, plus similar active pollution abatement projects on other segments of the main stream and tributaries that presently contribute or pose future threats of additional pollutants, will, from a chemical standpoint, bring about major fish habitat improvements. Although most of the M.W.I. projects would involve physical and/or water temperature changes which would have some degree of detrimental effect on anadromous and catadromous fishery resources, construction and operation of Tocks Island Reservoir will be the most critical feature.

218. It is not possible, currently, to formulate realistic plans or recommendations to counter the barrier effects that Tocks Island Dam will have on the anadromous and catadromous fishery resources of the Delaware Basin in the future. Intensive studies regarding the feasibility of installation and operation of fish passage devices will be required coincident and integrated with actual planning and construction of the Tocks Island Project, and quite possibly, continuing into the operating life of the reservoir.

219. The Tocks Island Project can be constructed and operated to minimize fishery problems which are associated with the temperature of downstream releases. In order to maintain post-project fishery resources for many miles below the dam, including both the resident species and the migratory ones, provisions must be made for draw-off from various levels of the deep reservoir, as would be possible through use of a tower, to allow favorable water temperature conditions during critical seasons.

Big Game

220. The current problems that are associated with the very important deer resources of the basin must be solved, or minimized greatly, or the resource will be of reduced consequence in the near future. A deer herd equal to its existing population level should be adequate in supplying future human needs if the resource is fully available for public use and the habitat is maintained in a condition suitable to support a herd of this size without excessive costs or damages. Although considerable effort has been, and is being directed toward balancing deer numbers with habitat and with human demands on both, serious problems are still apparent and the future portends greater difficulty. A broader deer management program is necessary.

221. State game agencies must be given both greater legal authority and more public support to successfully initiate and maintain a deer management program of the consequence that is required. Legal authority can be given by the legislatures of the States involved. The realization of greater backing and cooperation from sportsmen will require extensive public information and education endeavors.

222. The program will require funds in larger amounts than are presently available. Since hunting license fees are the principal source of game management funds, it is apparent that individual charges levied on deer hunters must be increased to an amount where the total sum derived will underwrite the costs of the program required.

223. Much can be done toward solving the general problems related to deer in the basin by opening most of the area to public hunting. This would provide local and visiting deer hunters with the opportunity to make full use of the resource. It would also allow annual manipulation of herd size to match changing habitat conditions through public hunting harvest, the most feasible and remunerative control method available.

224. Since most of the deer habitat in the basin is and will remain in private ownership for primary land-use purposes other than public deer hunting, maximum effort is needed to work out feasible methods whereby deer hunting will be possible without conflict with basic interests of various landowners. Active public information and education programs, to reach both the private landowners and the sportsmen, will be of some value in improving sportsman-landowner relations, which in itself should result in

opening to hunting use some of the areas that are now closed. It may be feasible to provide some compensation to landowners as payment for public benefits provided through opening lands. Special efforts are needed in the Upland to open to at least limited public use the many individual large areas that are now posted by sportsmen clubs, resort interests, public utility groups, and other single or group owners. In addition to public information and education, and possibly compensation, special guaranties against damages and varying systems of regulation of hunting use will be needed to open some of the large habitat blocks in the Upland. Opening presently closed lands to public use for deer hunting in the Piedmont and Coastal Sections will also require some special efforts. Expanded programs to educate landowners as to the advantages of public hunting as a herd control measure will be of particular value in those areas subject to, or threatened with, serious damages to crops or other vegetative cover due to excessive deer populations. Another solution applies particularly to areas having excessive deer numbers which are posted due to high human populations. Many of these areas can support some public hunting through coordinated effort with landowners and public officials wherein specific regulations are formulated which allow controlled public hunting and harvest of deer and still assure maximum protection of life and property.

225. There will be instances where private lands which provide important deer habitat and would be of high value as public hunting area cannot be opened through education, public relations, or compensation endeavors. In such instances where the need is particularly great, attempts should be made to acquire or lease such areas either primarily for the deer values involved or in conjunction with other fish and/or wildlife benefits included.

226. Public hunting opportunity and harvest control conditions can be improved somewhat, particularly in the Piedmont Section of the basin, through all feasible use of existing public lands and those which are acquired in the future. Most of the larger State Parks which are now closed to gunning could support at least limited deer hunting use. Since deer seasons normally occur in the late fall or early winter, when primary uses of park areas are usually dormant or greatly restricted, suitable agreements should be possible on many of these units which would permit some sort of public hunting opportunity.

227. Immediate action is needed in those areas of the basin where serious deer overpopulation problems exist or are threatened. In most cases it will be necessary to first reduce deer numbers to a point where they are not in excess of the existing carrying capacity of the habitat. The long range management of such problem areas will be directed toward maximum habitat preservation and

improvement in order that balanced conditions provide as many deer as possible to help fulfill the future needs of Delaware Basin sportsmen.

228. When deer removal is necessary, whether it be a major reduction in problem areas or annual harvests throughout the basin, every effort should be made to achieve the removal of excess animals through either special or regular public deer hunting seasons. In some special cases it may be necessary for personnel of State conservation agencies to effect immediate removal of problem deer through live-trapping and re-release or through killing. Such occasions should be kept to the absolute minimum, however, since they are usually ineffective as a long-term remedy, require costly use of limited game-management funds, men, and equipment, create unfavorable public reaction, and provide no recreational return to hunters.

229. Deer habitat conditions must be improved in problem areas throughout the entire basin if the resource is to retain its current recreational importance for future generations. Since the carrying capacity of the deer range, particularly in the Upland and Piedmont Sections of the Delaware Basin, is dependent on the amount of low, woody growth available during the winter season, the major opportunity for improving deer habitat exists in and near forested areas. A method, which has been adopted with success on some of the State-owned lands in parts of the Upland and Piedmont Section of the Basin, involves portional or plot cutting annually in extensive tracts of pole-stage or more mature trees. The method is of immediate value when the cutting is done in the late fall or winter since the smaller branches and twigs are dropped to near-ground level where they can be utilized by feeding deer while still of food value. This immediate availability is of particular importance in problem areas of excessive deer use since pressures are relieved on the local supply of low growing woody plants and a portion of the existing habitat is spared for future use. The method also has continuing values in that woody sprouts and other vegetative growth of importance as deer food usually come in during subsequent growing seasons. In some instances preferred food species are planted in the cut over areas to supplement or replace natural growth. Various modifications of this habitat improvement procedure could be adapted to most of the deer areas of the basin except within the Catskill Forest Preserve where such cutting would violate a provision of the State Constitution. While continuation and expansion of the program is necessary on State-owned areas, it is even more important that workable methods be developed for and implemented on, a significant portion of the 3 million-odd acres of privately-owned forest lands of the basin. Accomplishing this will require considerable efforts in coordination with landowners. Specific plans will have to be made for each

individual holding, and it is always desirable to undertake such cuttings as forest stand improvement measures. To be effective, this method must, without exception, be coordinated with adequate regulation of the local deer population through hunter harvest to levels which control browse damage to forest stands, including seedling and more advanced stages within reach of deer.

230. Existing habitat, particularly that which provides public hunting opportunity, should be protected against destruction or unfavorable alteration whenever possible. If destruction is unavoidable, such as is the case in some types of land-and water-use practices necessary for purposes of public or private welfare, every effort must be made to find and institute the most feasible mitigating features. Two practices which are particularly destructive to deer habitat in the Delaware Basin are strip mining and reservoir construction.

231. The destruction related to strip mining that has occurred in the past can be countered somewhat and that of the future partially avoided if necessary action is instituted. Restoring abandoned strip mines to valuable habitat is possible if sufficient funds for the study and work can be obtained by the State game agencies. In most instances the restoration will require backfilling or regrading followed by planting or seeding with specific woody and herbaceous cover best suited for each individual situation.

232. Strip mine destruction of deer habitat can be avoided or minimized in future years if suitable laws are formulated and enforced concerning the responsibilities of strip mine operators. Since present procedures are also destructive of vital land and water resources, as well as game habitat, due to their aggravation of erosion and pollution problems that have importance to the entire human populations of the regions affected, general regulations to protect the public interest will also benefit deer resources materially. Required backfilling, mine sealing, and reforestation are paramount among the needed regulations.

233. The Major Water Impounding Reservoirs included in the comprehensive water development plan for the basin will destroy or unfavorably alter lands important as deer habitat and public hunting areas. Phase I reservoirs will affect 19,000 acres and Phase II an additional 16,000 acres. These habitat and hunting opportunity losses must be mitigated to preserve the values associated with the deer resources of the basin. The most feasible method of partially replacing the values that will be lost is through improvement of habitat qualities and public hunting opportunities on existing deer range, preferably in juxtaposition to each area of destruction. Improvement on these areas can also serve to mitigate other upland game losses. Although reservoir data are not firm enough to draw

specific plans for each site, preliminary surveys indicate that mitigation is possible and that such action to protect public values involved is justifiable. Since 4 different States are involved and since each has a vested interest in the deer resources within its boundaries, mitigation should be accomplished on bases which effect replacement within the State where losses are incurred. Mitigation of deer resource losses resulting from Phase I reservoir construction will necessitate improvement of habitat and public hunting opportunities on a total of some 24,000 acres of deer range, all in the Upland Section of the basin. Of this total 2,500 acres will be needed in New Jersey, 6,700 acres in New York, and 14,900 acres in Pennsylvania. The total losses to the deer resource which will result from construction and operation of Phase II reservoirs will require improvement of habitat and hunting opportunities on a total of 22,700 acres of basin deer range; 16,800 acres in the Upland Section, 4,900 acres in the Piedmont Section and 1,000 in the Coastal Section. Needs according to State boundaries are: 1,250 acres Delaware (250 acres Piedmont and 1,000 acres Coastal); 4,650 acres in New Jersey, all in the Piedmont; 5,600 acres in New York, all in the Upland; and 11,200 acres in Pennsylvania, all in the Upland. Actual habitat areas to be improved and methods of improvement for each can be chosen most feasibly at the time of and in conjunction with firm plans for construction at each reservoir site.

Upland Game (forest game)

234. Problems associated with smaller forms of forest game are not as widespread as those bearing on the deer resource. The small game animals native to the woodland portion of the basin support recreational use by a significant number of sportsmen, however, and their numbers should be protected and increased, if possible, for the enjoyment of future generations. Habitat conditions and public hunting opportunities that are related to grouse and hare resources of the basin can be benefited materially if the deer program discussed above is accomplished, since the range requirements of and hunting areas for these 2 smaller species of forest game include many of the same mixed-forest, edge, and brush areas that are used by deer.

235. The full potentials of the turkey resource can be realized through a continuing program of intensive management to restore the bird in optimum numbers on the large existing areas of suitable range. A basic item that should be included in the management program is further research concerning stocking and winter feeding procedures. Funds to underwrite the related costs should be obtained from special license fees levied on turkey hunters. This measure would be applicable now in the Upland Section of Pennsylvania since huntable populations of turkeys currently exist and soon may be possible in the New York portion of the basin where recent evidence in some areas indicates that harvestable populations could occur in the next few years.

236. As in the case of deer, the outright destruction of habitat important to forest game must be avoided or mitigated whenever possible. The suggested solutions related to strip mine destruction of deer habitat apply directly to forest game. The mitigation that has been discussed and is recommended for deer habitat losses to be caused by M.W.I. project construction should offset the effects of most of the loss or alteration of 25,000 acres of forest-game habitat and hunting area that the total water development plan would entail.

Upland Game (farm game)

237. Many of the complicated and interrelated problems associated with habitat conditions for and public utilization of the valuable farm-game resources of the Delaware Basin defy feasible solution. Some of the current difficulties can be remedied, however.

238. The existence of suitable habitat is basic in providing harvestable surpluses of farm-game animals for public enjoyment. There is little opportunity to avoid the destruction of habitat when it occurs as the result of major alterations in the primary uses of land, such as that currently prevalent in many portions of the Piedmont Section of the basin, which involved the conversion of farm land to industrial, municipal, residential, and related purposes. Losses of this type plus existing natural deficiencies can be partially countered through qualitative improvements of habitat on the lands remaining.

239. Since farm-game animals are usually incidental by-products of a quite different primary land-use and since the majority of the areas that are important as habitat are privately owned and subjected to varying types of agricultural management, farm-game welfare is largely dependent upon how individual farmers utilize their properties.

240. Maintenance of sound land-use practices is the basic prerequisite to preservation and enhancement of game resources on the agricultural lands of the basin. Basin wide adoption of the soil and water use principals recommended by the Soil Conservation Service and local Soil Conservation Districts, which are designed to have long term values in reducing erosion and maintaining soil productivity, will benefit agricultural uses and also provide the necessary base for various types of specific programs to develop or maintain good productive wildlife habitat.

241. There are 2 broad possibilities for improvement of farm-game habitat in the Piedmont and Coastal Sections of the basin. One is the avoidance of current practices which are destructive. The other involves adopting alternative or entirely dissociated methods

which are valuable. Practices to be avoided wherever possible include: filling sloughs and swales, green stubble burning, elimination of fence balks and hedgerows, night hay mowing, grazing woodlots, and fall plowing. Favorable practices to be encouraged or instituted include: food patch plantings; establishing and retaining small permanent tree and shrub plots and lanes as escape and winter cover; leaving small portions of grain crops standing after harvest, development of edge, protection of ground cover, and plot cutting in mature woodlots; brush piling; and establishment of permanent sod areas.

242. The benefits associated with wildlife habitat preservation and development are less obvious to the farmer than are those related to practices contributing directly to agricultural productivity. Wildlife interests must provide land-owners with greater incentive to develop habitat. Expansion of various public information and cooperative farm-game programs in which State conservation agencies are currently engaged will help to some extent. This must be supplemented by more aid from trained personnel and, in many instances, by monetary or other compensation, if major improvements are to be realized. The general program required will necessitate considerably greater expenditures than are currently possible. The most feasible source of funds for these purposes is the large group of hunters who derive recreational benefits from the farm-game resource.

243. Most of the habitat improvement practices discussed above have already been instituted to some extent on existing State-owned public hunting grounds. There has been a lack of sufficient funds to realize the full potentials, however. Although the percentage of State-owned land is small in the farm-game section of the basin, expansion of habitat improvement works on it, with particular emphasis on those practices applicable to woodlands, will be of considerable importance as a supplement to improvements accomplished on adjoining private lands. A further supplement to the farm-game resource can be accomplished through habitat improvement work on lands controlled by private sportsmen's clubs.

244. The farm-game resources of the basin will be of little value to the expanding populations of the future unless current hunting opportunity conditions are improved materially and then maintained. It is not realistic to believe that sufficient lands can be placed in State ownership to satisfy the needs of the hunting public. Some State acquisition will help as a supplement in specific areas, but the major chance for increasing hunting area is related to the use of privately-owned land. The same public information endeavors and cooperative farm-game programs suggested above relative to habitat improvements can be adapted as vehicles through which private lands are opened to public hunting use. The success of

ventures to open closed lands will be dependent in part upon how well landowners and sportsmen understand each other's problems and needs. In many instances, "understanding" alone will be inadequate to accomplish the opening of presently closed lands, or to avoid additional closure in the future. In such cases landowners must be provided with some sort of reasonable compensation for public hunting benefits that they are in a position to provide.

245. The day is at hand in portions of the Delaware Basin when sportsmen must provide payment to landowners to hunt farm game. Payment may be direct or through State game agencies' programs. There is a danger that the widespread practice of direct payment will eventually result in a full-scale swing to pay-as-you-go hunting, controlled by private commercial interests, and that public interests and investments in the game resources could suffer materially. It is apparent that State game agencies must have the funds and support by the sportsman that is necessary to set up and administer programs to assure public hunting use on most of the private farmlands, or increasingly larger portions of the basin will lack the equal opportunity aspects that have been part of the heritage associated with hunting privileges in the United States in the past.

246. The M.W.I. projects will destroy or unfavorably alter a total of over 40,000 acres that are of importance both as habitat and hunting area for farm-game in the basin. The losses can be offset through intensive development of habitat and public hunting facilities on land near the areas of destruction. About 28,000 acres of the total area needed for mitigation of project-related deer losses can be developed to also offset farm-game resource losses. Additional lands totaling 17,000 acres will be needed to offset farm-game losses where deer resources are not involved.

Waterfowl

247. Waterfowl, and man's recreational uses thereof, are dependent mainly on the prevailing status and availability of wetland habitat. Shore birds and aquatic fur animals are also dependent on wetlands. Since natural wetland conditions and the associated human land-and water-use activities which alter them vary widely throughout the length of the Delaware Basin, a program for preservation and enhancement of waterfowl and related resources requires different procedures according to the area involved.

248. The main opportunities for increasing waterfowl value in the Upland and Piedmont Sections of the basin include improvement of public access facilities to existing waterfowl areas and habitat improvements at existing and potential wetland habitat areas with

development of provisions for public access to them. Habitat development would provide some nesting habitat for ducks and would be of particular importance to sportsmen and naturalists in attracting temporary stopovers by greater numbers of the ducks and geese that normally cross this area during fall migration. It would also have incidental benefits to aquatic fur animals in most areas. The main improvements needed are greater areas of open marsh and shallow water, with associated food-plant producing qualities, developed both on existing wooded swamps and at potential marsh sites. Generally, the improvements would involve shallow impoundment of such areas, preferably with provision for control of water levels to allow the manipulation necessary to discourage undesirable plants and favor those that are of value as duck food. For the most part, the feasible development sites that are available are small, being less than 20 acres in area. The few large areas with impoundment possibilities that do exist deserve special consideration. As a supplement to specific programs for waterfowl marshs and pond development on public and private lands, similar areas can be developed in many instances through use of road fills and culverts as dikes and control structure locations. Coordination between highway and wildlife conservation interests could result in major wetland habitat improvements at comparatively low actual costs.

249. It is important that the wetland habitat destruction associated with Major Water Impounding Reservoir construction be offset, since most of the losses will occur in the upper portions of the basin where waterfowl and aquatic fur-animal habitat is in short supply. Losses can be mitigated through habitat improvements, similar to those described above, on lands close to the project areas causing the destruction.

250. Unlike the upper portions of the basin, the gross wetland area of the Coastal Section is large and is of high value both as waterfowl habitat and as the site of either actual or potential public use. The estuarine wetland complex has additional value as living area for muskrats and numerous species of shore birds. To offset continued encroachment on this habitat, there must be a program of acquisition to effect preservation of the best wetland units, supplemented by improvement or development on these and other marshes and waters. The supplement is necessary to offset the destruction and unfavorable alteration of tidal marshes that has occurred in the past and is still occurring as the result of various practices related to human "progress" along the Delaware River Estuary.

251. In most instances, improvement works would involve diking, pothole construction, impoundment, or blind-ditching to maintain more shallow water surface within or bordering existing

tidal marshes. One type of new development work would be impoundment of controllable level, shallow water areas, above the tidal zone in the valleys of streams tributary to lower Delaware River and Bay. Another type of development that has been used successfully in some portions of Coastal Section of the basin consists of shallow pond and pothole construction in and near the farmlands bordering the tidal marsh zones. Acquisition and development for habitat purposes is needed most in the area between Trenton, New Jersey and Delaware City, Delaware where past destruction has been of serious proportions.

252. Opportunities for public use of the waterfowl resources can be improved in several ways. Better access facilities can be provided on several of the units that are currently in State ownership. The program of additional purchase to preserve the better habitat areas mentioned above will also be of value in presenting additional opportunities for hunting or nature study by the public. Acquisition with subsequent habitat improvement or development that is made to offset other wetland losses can increase both the quality and the quantity of waterfowl areas that can be opened for public recreational use.

253. There are possible ways other than those direct measures discussed above, through which the waterfowl resource values can be protected in part from threatened destruction of habitat. Solutions along the portion of the estuary upstream from Delaware City, Delaware are associated with navigation works. Those bearing on wetlands areas below Delaware City are related to mosquito control and, to some extent, highway endeavors.

254. Spoil disposal activities associated with navigational improvements have been a major feature in the destruction of wetlands along most of the tidal portion of the Delaware River. Future losses can be minimized to some extent through careful choice of spoil sites to avoid use of the better habitat units; also, spoil can be used to replace in part at least habitat values destroyed. In some cases it should be possible to deposit spoil in otherwise unproductive deep areas, bringing the land surface up to a specific elevation favorable for the eventual creation of marsh habitat. Spoil can also be used to form dikes or gut plugs in some areas where impoundment would improve habitat conditions for waterfowl. There is also a chance to recover some habitat values where spoil must be deposited to heights considerably above tidal effects. Some of these areas would be of value in conjunction with bordering wetlands, if placed in grain production for waterfowl feeding purposes, similar to current practices on the Killcohook Disposal Area in Salem County, New Jersey.

255. Ditching and draining activities associated with mosquito control have decreased the fish and wildlife productivity of segments of the tidal marshes bordering Delaware Bay. This unfavorable alteration of marsh habitat can be rectified and, in future instances, avoided by substitute measures which are of value in creating conditions which are favorable to waterfowl and unfavorable to insect production. Commendable progress has been made toward coordinating mosquito-control and waterfowl interests in both New Jersey and Delaware during the past few years. It has been found that several variations of measures to hold water on the tidal marshes can result in effective and lasting mosquito control and still be of value to waterfowl and/or muskrats. A method that is particularly beneficial to waterfowl involves gradual drawdown of water levels on impounded marshes during summer months, with reflooding in the fall after the end of the mosquito breeding season. The growth of annual plants, which are productive as waterfowl food, is favored and the fall flooding makes the food produced readily available to migrating and wintering ducks.

256. Highway embankments can be used to improve waterfowl habitat in the Coastal Section in a similar manner to that mentioned above in discussion of the Upland and Piedmont Sections. The method has already been used with considerable success at several places in the tidal marshes of Delaware. Road embankments can sometimes be used as dikes, with control structures located at bridge or culvert areas, creating permanent-or variable-level impoundments, and producing excellent wildlife habitat at a low cost.

SECTION VII - FISH AND WILDLIFE PLAN

257. The following plan is presented as a general guideline of ways and means by which the more important fish and wildlife resources of the Delaware Basin can be protected and improved for man's present and future enjoyment.

Fresh-Water Fisheries

258. Important elements necessary for the protection and/or improvement of the fresh-water fishery resources of the basin are to:

a. secure public fishing rights on segments of trout streams which have potential for greater use and/or production; followed by development of access facilities, stream habitat improvement, reclamation, and/or stocking with hatchery-reared trouts wherever necessary and feasible. Upland Section streams with segments having potentials include: East and West Branches of the Delaware River, the Little Delaware, Tenmile, Mongaup, and Neversink Rivers, and Basket, Callicoon, Hankins, and Willowemoc Creeks, and East, Trout, and Coles Clove Brooks and Shingle, Bush, and Beaver Kills in New York; the Delaware River from the mouth of the East Branch to the mouth of the Lackawaxen River in both New York and Pennsylvania; Brodhead, Pocono, Paradise, Bushkill, Shohola, Aquashicola, Mauch Chunk, Bear, Pine, and Locust Creeks, and the Lackawaxen and Lehigh Rivers in Pennsylvania; and Flat Brook in New Jersey. Some of the Piedmont Section streams having segments with possibilities for this action are: Wyomissing, Spring, Antietam, Pickering, Valley, White Clay, Chester, Ridley, and Pocopsin Creeks and Birch, Buck, and Broad Runs in Pennsylvania; and the Paulins Kill, the Pequest and Musconetcong Rivers, Lockatong, Pohatcong, Lopatcong, Ramseyburg, and Ebenezer Creeks, and Stony Brook in New Jersey. Similar type possibilities in the Coastal Section include reaches of the following New Jersey Streams: Oldmans, Raccoon, Swedesboro, Mantua, Big Timber, Ellisburg, Woodcrest, and Menantico Creeks, and Big Lebanon and Berrymans Runs.

b. develop suitable and adequate access facilities for fishermen to bodies of water, otherwise open to public use, which support or could support desirable species of fish; followed by reclamation and management of such

waters wherever necessary. Some of the basin waters having outstanding potentials include: both shores of the Delaware River between Port Jervis, New York and Trenton, New Jersey; Mongaup Falls, Neversink, Rio, Swinging Bridge, Toronto, and Pepacton Reservoirs in New York; and Lake Wallenpaupack, Rose Pond, and Little Twin, Big Twin, Hunters, and Beach Lakes in Pennsylvania.

c. acquire public fishing rights on currently closed ponds, lakes and reservoirs which support, or could be developed to support, desirable fisheries, particularly in the Piedmont and Coastal Sections of the basin; to be followed by development of access facilities and/or habitat management where necessary.

d. construct, develop, and manage headwater impoundments, except in New York, specifically for public fishing. Where such impoundments are situated on trout streams, they should be designed also to facilitate low flow augmentation and temperature control of waters below the dams whenever possible.

e. create large impoundments capable of supporting warm-water pond fisheries for public use, except in New York. Several good potential sites are: Cat Swamp in New Jersey, and on Jacoby, Jordan, and Black Creeks in Pennsylvania.

f. open all fishable waters occurring in parks of the basin to maximum feasible public fishing use.

g. install stream improvement devices for fish on that section of the Paulins Kill in New Jersey which is altered by the Small Watershed Project currently active there.

h. stop acid, culm, and silt pollution of upstream basin waters resulting from coal mining operations.

i. reduce present and minimize future contamination of basin waters resulting from domestic, municipal, and industrial wastes. This will protect and benefit marine, catadromous, and anadromous fishery resources as well as those of inland fresh waters.

j. provide adequate access facilities and necessary sanitary, parking, and boat-launching developments to allow maximum public fishing use at each of the pond fisheries that is created by M.W.I. project development.

k. provide water releases below each M.W.I. project dam to meet volume and temperature requirements necessary to protect, and enhance if possible, fishery values of downstream reaches (including anadromous, catadromous, and inland fresh-water fishery resources).

l. mitigate the losses of available stream fishery which will result from M.W.I. project construction through improvement of public fishing opportunities on nearby waters having similar fisheries to those lost. Means whereby this can be accomplished are presented in the following table on an individual reservoir basis.

Table 17.--Mitigation of stream fishery losses resulting from M.W.I. projects.

M.W.I. Project Involved and Phase	Type of Stream Fishery Loss to be Offset	Method of Mitigation Possible		
		Type	Amount	Location
Tocks Island-I	Trout	Acquire public fishing rights along, and develop road to, an existing trout stream.	1.5 miles	Pennsylvania - Bushkill Creek
Tocks Island-I	Trout, Smallmouth bass, and Walleye	Improved access to similar fishery which is currently underutilized.	Seven 5-acre access sites with sanitary, parking, and boat-launching facilities.	Pennsylvania - North Branch of the Susquehanna River.
Tocks Island-I	Trout	Acquire public fishing rights along, and develop use facilities on existing trout stream.	22 miles	New Jersey - on 1 or more of the several larger trout streams in the northern third of the State.
Tocks Island-I	Trout and Smallmouth bass	Acquire public fishing rights along, and develop use facilities on existing streams supporting trout and smallmouth bass.	3.5 miles	New Jersey - stream segment in northern third of State.

(Table 17 continued)

M.W.I. Project Involved and Phase	Type of Stream Fishery Loss to be Offset	Method of Mitigation Possible		
		Type	Amount	Location
Sterling - I	Trout	Acquire public fishing rights on existing trout stream	3.0 miles	Pennsylvania-Pike or Monroe County
Basher Kill - I	Trout	Acquire public fishing rights on existing trout stream	10.2 miles	New York - Orange or Sullivan County
Basher Kill - I	Mixed warm-water fishery	Acquire public fishing rights on existing stream supporting mixed warm-water fishery	3.0	New York - Orange or Sullivan County
Basher Kill - I	Trout, Smallmouth bass, and Walleye	Improve access to similar fishery which is underutilized	One 5-acre access site with sanitary, parking, and boat-launching facilities.	Pennsylvania-North Branch of the Susquehanna River
Basher Kill - I	Trout and Smallmouth bass	Acquire public fishing rights along and develop use facilities on existing stream supporting smallmouth bass and trout	1.0	New Jersey - Northern third of State
Bernville - I	Trout	Acquire public fishing rights on existing trout stream	2.0	Pennsylvania-Spring Creek
Hawk Mountain--II	Trout	Acquire public fishing rights on, and develop, existing trout stream	4.5	New York - Delaware County

(Table 17 continued)

M.W.I. Project Involved and Phase	Type of Stream Fishery Loss to be Offset	Method of Mitigation Possible		
		Type	Amount	Location
Shohola Falls--II	Trout	Acquire public fishing rights on, and develop, existing trout stream	4.2 miles	Pennsylvania-Wayne County
Beltzville - II	Trout	Acquire public fishing rights along existing trout stream	6.5 miles	Pennsylvania-Carbon or Monroe County
Aquashicola - II	Trout	Acquire public fishing rights, and develop public use facilities, along existing trout stream	10.0 miles	Pennsylvania-Carbon or Monroe County
Paulina - II	Trout	Acquire public fishing rights, and develop public use facilities along existing stream supporting trout, bass, and carp	6.0 miles	New Jersey - Piedmont Section
Pequest - II	Trout	Acquire public fishing rights, and develop public use facilities along existing trout stream	7.1 miles	New Jersey - Piedmont Section
Hackettstown - II	Trout and Smallmouth bass	Acquire public fishing rights, and develop public use facilities along existing stream supporting trout and bass	5.0 miles	New Jersey - Piedmont Section
New Hampton - II	Trout and Smallmouth bass	Acquire and develop, for public fishing use, stream supporting smallmouth bass and trout	6.0 miles	New Jersey - Piedmont Section

(Table 17 continued)

M.W.I. Project Involved and Phase	Type of Stream Fishery Loss to be Offset	Method of Mitigation Possible		
		Type	Amount	Location
Newtown - II	Warm-water fishery	Acquire public fishing rights on stream supporting warm-water fishery	10.0 miles	Pennsylvania-Bucks County
French Creek-II	Trout	Acquire public fishing rights on trout stream	7.0 miles	Pennsylvania-Chester County
Newark - II	Trout and warm-water fishery	Acquire public fishing rights on stream supporting both trout and warm-water fish	2.5 miles	Pennsylvania-Chester County
Newark - II	Trout	Acquire and develop existing trout stream for public fishing use	6.0 miles	Delaware - New Castle County

Phase I Subtotals:

Total stream miles where both acquisition and development are required	=	28.0
Total stream miles where only acquisition is required	=	18.2
Grand total stream miles needed	=	46.2
Total special 5-acre access sites where streams acquisition is not necessary	=	8

Phase II Subtotals:

Total stream miles where both acquisition and development are required	=	48.8
Total stream miles where only acquisition is required	=	26.0
Grand total stream miles needed	=	74.8

Table 17 Summary (Including both Phase I and Phase II reservoir projects):

Total stream miles where both acquisition and development are required	=	76.8
Total stream miles where only acquisition is required	=	44.2
Grand total stream miles needed	=	121.0
Total special 5-acre access sites where stream acquisition is not necessary	=	8

m. counter the destructive effects of the Sterling project on trout spawning by buying and supplying to the Pennsylvania Fish Commission approximately 100,000 trout fingerlings each year.

n. build a new fish hatchery for the New Jersey Division of Fish and Game below the Pequest Dam provided with a firm daily water supply of $3\frac{1}{2}$ million gallons at 52° F., as replacement for the existing hatchery and water supply that will be destroyed by the project.

Marine Fisheries

259. Important elements necessary for the protection and/or improvement of marine fishery resources of the basin are to:

a. formulate and implement a comprehensive survey of commercial and recreational uses of marine fishery resources of the basin, coordinated among all State, Federal, and private interests concerned as to timing and procedures.

b. formulate and implement a complete, coordinated estuarine research program, including study of all finfish and shellfish species and related habitats having existing or potential values for commercial and/or recreational reasons. This program should involve studies of the inter-relationships of interests utilizing the Bay area and resources thereof.

c. develop new public boat launching areas along the Delaware Bay, strategically located to permit optimum recreational use of the resources available.

d. acquire and develop for public fishing use, some of the few existing segments of the Delaware Bay shore that are suitable for bank fishing purposes.

Anadromous and Catadromous Fisheries

260. In addition to pollution abatement and water release aspects, as treated in elements i, and k, respectively, of the preceding Fresh-Water Fishery section of this plan, special provisions will be necessary at the Tocks Island project in order to protect existing and potential values of anadromous and catadromous fishery resources of the basin. Important aspects at Tocks Island will be to:

a. construct project outlet works which will permit draw-off from various levels of the reservoir, as would be possible through use of a tower, followed by coordination between project operators and appropriate fishery conservation agencies throughout the project life to insure, insofar as is possible, seasonal downstream releases at the most favorable volumes and temperatures for various fishery resources concerned.

b. conduct special studies during actual planning and construction stages, and thereafter if necessary, by qualified fishery biologists to determine and develop appropriate fish passage measures to offset the detrimental barrier effects that the dam will have on valuable migratory fish resources; feasible structural and operational alterations of the project to be developed and initiated in cooperation with the authorized construction agency.

Wildlife

261. Important elements necessary for the protection and/or enhancement of wildlife resources of the basin are to:

a. provide legislation and public backing necessary to permit realistic management of deer resources for the public benefit.

b. open a major part of the privately-owned deer range of the basin to public hunting use, through compensation to owners for privileges provided if necessary. In the case of key areas that cannot otherwise be opened, to purchase such units specifically for public hunting purposes.

c. increase and maintain the carrying capacity of basin deer range, on both public and private lands, through various habitat improvement measures including features such as annual plot cutting in wooded sections that are in or beyond the pole-stage, and reclamation of denuded abandoned strip-mine areas which exist in the Upland portions of the Schuylkill and Lehigh drainages in Pennsylvania.

d. maintain deer populations at a level commensurate with carrying capacity of habitat; where deer herd reductions are necessary to accomplish this by means of public hunting.

e. enforce laws requiring strip-mine operators to backfill and replant the lands torn up in their mining endeavors, thus protecting various natural resources including habitat for deer and smaller types of forest game.

f. re-establish turkey populations in optimum numbers within all suitable habitat zones of the basin.

g. enhance the farm-game resources of the basin both through improvement of habitat and through expansion of public hunting opportunities on privately-owned farmlands, to be accomplished by various methods including in instances when necessary, reasonable compensation to landowners for public benefits provided.

h. expand upland-game habitat improvements on State-owned lands and on lands controlled by private sportsmen's groups.

i. acquire and develop public hunting grounds, where the opportunity and need prevails, to supplement farm-game resources on associated habitat and hunting areas.

j. expand small marsh and pond development programs in the Upland and Piedmont Sections of the basin, and preserve and develop the few existing large wetland areas in non-coastal portions, to preserve and enhance waterfowl and fur animal resources. Some of the larger areas deserving preservation include the Basher Kill marshes in New York and the Shohola Falls and Wolman Marshes of Pennsylvania.

k. improve, insofar as possible, habitat conditions on existing or potential waterfowl areas in the Coastal Plain Section of the basin, including those that are

nor or will be protected by public ownership and those areas in private ownership with low vulnerability to other land-use changes; impoundment or other water surface creation measures to be accomplished with consideration for mosquito-control problems. Also preserve, and develop where feasible, the better habitat units still existing in the zone of major destruction of estuarine marshes between Trenton, New Jersey and Delaware City, Delaware, some of the units deserving consideration being: 1300 acres at the Crosswicks Creek-Trenton Marshes; 250 acres of fresh tidal marsh and water along Pennsauken Creek; 700 acres of marsh along Rancocas Creek; 180 acres of mudflat and shoal at Fish House Cove; 250 acres of marsh at Hermesprota Creek; 1500 acres of marsh, swamp and shoal in the Monds Island-Repaupo Creek - Chester Island area; 960 acres of fresh tidal marsh on Raccoon Creek and 1200 acres on Oldmans Creek, all upstream from U. S. Route 130; and 850 acres along the Christiana River, including 400 acres at Churchmans Marsh.

l. improve public waterfowl hunting opportunities through development of access facilities to waterfowl areas that are otherwise open or can be opened to public hunting use and acquisition of areas, with or without development, for public hunting use when public needs justify the expenditures. Possible locations for this latter measure include the following units in the Coastal Section: the upper reaches of Big Timber, Mantua, Raccoon, and Oldmans Creeks, and portions of the tidal marshes of southern Salem and northern Cumberland Counties, all in New Jersey; and tidal marshes in the vicinity of Augustine Creek, Cedar Swamp, Duck Creek, St. Jones River, Primehook, and between Kitts Hummock and the St. Jones River, all in Delaware.

m. develop and implement feasible measures for the disposal of spoil from navigation works which will spare better habitat units and offset unavoidable destruction through use of spoil to improve, replace, and/or create waterfowl habitat.

n. continue and expand recent efforts to discover and adopt insect control and waterfowl development methods that are mutually acceptable and beneficial to both interests.

o. develop waterfowl habitat in conjunction with road building endeavors.

p. mitigate losses of existing wildlife habitat and/or public hunting areas which will result from M.W.I. project construction through improvement of habitat and/or public hunting opportunities on nearby lands. Means whereby this can be accomplished are presented in the following table on an individual reservoir basis.

Table 18.--Mitigation of wildlife losses resulting from M.W.I. projects

M.W.I. Project Involved and Phase	Wildlife Species or Groups Affected: Deer	Forest Game	Farm Game	Fur Animals	Waterfowl	Woodcock	Mitigation Required: Type: Habitat Improvement	Public Hunting Opportunity	Acres of Land Needed	Location	Remarks
Phase I											
Tocks Island	X		X				X	X	9,400	Pa.-Pike or Monroe Co.	
Tocks Island	X		X				X	X	1,700	N.J.-Sussex or Warren County	
Tocks Island				X	X		X		1,200	Pa.-Pike or Monroe Co.	600 acres to be impounded
Sterling	X	X		X	X		X	X	200	Pa.-Wayne or Pike Co.	To include stream
Tobyhanna	X	X					X	X	3,800	Pa.-Luzerne, Carbon, or Monroe Co.	
Basher Kill	X	X	X				X	X	6,700	N.Y.-Orange or Sullivan County	
Basher Kill	X		X				X	X	1,500	Pa.-Pike or Monroe Co.	
Basher Kill	X		X		X	X	X	X	800	N.J.-Sussex or Warren County	
Basher Kill					X		X	X	3,100	N.Y.-Orange or Sullivan County	To include 2,500 acres of marsh
Bernville			X				X	X	3,000	Pa.-Berks County	

(Table 18 continued)

M.W.I. Project Involved and Phase	Wildlife Species or Groups Affected						Mitigation Required				
							Type				
	Deer	Forest Game	Farm Game	Fur Animals	Waterfowl	Woodcock	Habitat Improvement	Public Hunting Opportunity	Acres of Land Needed	Location	Remarks
Phase II											
Hawk Mt.	X	X					X	X	5,600	N.Y.-Del. County	
Shohola Falls	X	X		X	X	X	X	X	9,000 in three tracts	Pa.-Pike County	To include 1,200 acres of marsh
Beltzville	X	X	X				X	X	1,000	Pa.-Monroe or Carbon County	
Aquashicola	X	X	X				X	X	1,200	Pa.-Monroe or Carbon County	
Paulina	X		X		X		X	X	1,750	N.J.-Warren or Sussex County	To include 50 acres of shallow impoundments
Pequest	X		X				X	X	2,000	N.J.-Warren or Hunterdon County	
Pequest					X		X	X	2,800 in scattered parcels	N.J.-Piedmont Sect.	To include marsh or development of

(Table 18 continued)

M.W.I. Project Involved and Phase	Wildlife Species or Groups Affected: Deer	Forest Game	Farm Game	Fur Animals	Waterfowl	Woodcock	Mitigation Required: Type: Habitat Improvement	Public Hunting Opportunity	Acres of Land Needed	Location	Remarks
<u>Phase II</u>											
Hackettstown	X		X				X	X	900	N.J.-Piedmont Sect.	
New Hampton			X				X	X	1,560	N.J.-Piedmont Sect.	
Trexler			X				X	X	1,500	Pa.-Lehigh County	
Tohickon			X				X	X	2,000	Pa.-Bucks County	
Newtown			X				X	X	2,000	Pa.-Bucks County	
Maiden			X				X	X	3,400	Pa.-Berks County	
Maiden					X		X		1,000	Pa.-Berks County	320 acres to be impounded
French Creek			X				X	X	1,500	Pa.-Chester County	
Evansburg			X				X	X	1,600	Pa.-Montgomery Co.	
Newark			X				X	X	400	Pa.-Chester County	
Newark	X		X				X	X	250	Del.-New Castle Co.	
Christiana	X		X				X	X	1,000	Del.-New Castle Co.	
Christiana					X		X		-	Del.-New Castle Co.	ten $\frac{1}{2}$-acre potholes on State land

Phase I Subtotals:

Total acres needed for both habitat improvement and public hunting	=	30,200
Total acres needed for habitat improvement only	=	1,200
Grand total acres needed	=	31,400

Phase II Subtotals:

Total acres needed for both habitat improvement and public hunting	=	39,460
Total acres needed for habitat improvement only	=	1,000
Grand total acres needed	=	40,460

Table 18 Summary:

Total acres needed for both habitat improvement and public hunting	=	69,660
Total acres needed for habitat improvement only	=	2,200
Grand total acres needed		71,860

q. provide the New Jersey Division of Fish and Game with a 260-acre unit of bottom land located in northern New Jersey, complete with buildings and habitat and access improvements, and other necessary facilities, as replacement for existing game farm and public hunting lands which will be destroyed by the Tocks Island project.

SECTION VIII - RECOMMENDATIONS

262. It is recommended:

1. That preservation and enhancement of fish and wildlife resources, and provision for reasonable public use thereof, be a purpose of any water-use development project in the basin regardless of who shall finance, construct, and operate the project.

2. That the Fish and Wildlife Plan as outlined in the preceding section of this appendix be adopted as an integral part of the comprehensive plan for development of the Delaware River Basin.

REPORT ON THE

COMPREHENSIVE SURVEY

OF THE

WATER RESOURCES

OF THE

DELAWARE RIVER BASIN

APPENDIX K

USE AND MANAGEMENT OF LAND AND COVER RESOURCES

PREPARED BY

UNITED STATES DEPARTMENT OF AGRICULTURE

FOR

U. S. ARMY ENGINEER DISTRICT, PHILADELPHIA
CORPS OF ENGINEERS
PHILADELPHIA, PA.

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CHAPTER I

AGRICULTURE IN THE DELAWARE BASIN

PART A - INTRODUCTORY PERSPECTIVE FOR AGRICULTURE

SECTION I - INTRODUCTION

From forested and lake-studded mountain headwaters, past prosperous farms and factories, to 17th century New Castle near the Bay, the Delaware River flows through a dynamic segment of modern America.

Lands and water of the Delaware early welcomed uprooted families from many sections of Europe. Swedes, English, Dutch, Welsh, Irish, Germans, French, Italians -- previous nationality meant little in the new country. The amalgam which later became the United States largely was generated in this area in an agricultural and small trades setting.

The Delaware continues to be an historic stream. Some of its tributaries, such as the Schuylkill and Brandywine, were among the first in the nation to be so severely polluted with animal and industrial wastes that fish, wildlife and humans alike shrank from their stench and their contamination. Some of these same tributaries, in turn, were among the first to receive pollution control which partially restored their former beauty and usefulness.

The Delaware is small, as major rivers go, but it is a giant in many ways. Vast industrial plants, trade centers and transportation facilities have developed along its lower reaches. Their demands for food and fiber bolstered nearby agriculture during periods when agriculture was becoming less important in New England and the Southeast. Waters of the Delaware, utilized more and more intensively for industrial and domestic purposes and lately for irrigation, have been the subject of hundreds of discussions and studies. Water apportionment and use have been the subject of heated litigation in local, state and national courts. Recent growth in demand and limitation in supply have brought realization that planned, integrated use of its waters is necessary.

High gradient tributaries of the Delaware River often damage farms, homes and industries located on their own floodplains and, less frequently, contribute to damage along the mainstem. Yet, during summer and early fall, some of these rivulets become innocent-appearing trickles that cannot meet human demands from their flow. Some important tributaries flood almost annually; others cause serious damage only at infrequent intervals. Particularly devastating floods in 1945, 1953 and 1955 stirred local demand for public improvements to prevent recurrence of these losses and associated tragedies. Appeals for aid were transmitted to the Congress.

The Corps of Engineers was directed to make a comprehensive survey and to prepare an integrated plan for the control and utilization of the water resources of the Delaware River. The task of formulating this plan was to be shared by all state, interstate, municipal and federal agencies having a direct and long-standing interest in the problems and in any plans for development which may emerge from the survey.

The United States Department of Agriculture has agreed to estimate the present and future water requirements for agricultural purposes in the survey area and to determine how these needs may best be met, to determine the effect of land treatment and structural measures for flood prevention and watershed protection on high and low stream flows and on sedimentation and to determine the impact of inundation upon agricultural production capacity and resources. The resultant studies will not constitute a comprehensive survey of the agricultural resources of the Delaware River Basin and will not result in recommendations for an overall agricultural program for the Basin. They are part of a cooperative water resources survey of the Basin and adjacent water dependency areas to the East and will become reference materials appended to the final report.

SECTION II - SIGNIFICANCE OF THE DELAWARE BASIN

2-01. POPULATION GROWTH

Over five million persons -- one and a half million families -- live and work in the Delaware Basin, an area of less than 13,000 square miles. And we are told that today the Delaware Valley stands on the threshold of its real growth, despite the phenomenal strides it has made over the past decade! Another quarter million dwellings will be added by 1960.

Perhaps the most striking change that has come to the Delaware in the past few years is its housing. New housing sections are everywhere; this in turn reflects the industrial expansion. Not only has the Delaware area gained some 200,000 homes in five years, but it also has had created whole new communities. Three new sections of the Delaware Valley area are indicative: The Levittown-Fairless Hills area in Pennsylvania; the new Levittown in New Jersey; and the Brookside-Chestnut Hill section outside of Newark, Delaware. Built on open fields and former truck farm land, the Levittown-Fairless Hills developments soon will have a population of some 80,000, which is as large as Wilkes-Barre, Pennsylvania. The New Jersey Levittown will have a population of an estimated 50,000, making it a community the size of Elmira, New York. The Brookside-Chestnut Hill development, although much smaller, will have a combined population equivalent to the fourth city in the State of Delaware.

The examples cited above, of course, are the giants, but for each giant there are a hundred smaller developments scattered throughout the

Basin. A survey made by the Public Service Corporation of New Jersey, a large private utility company, showed that in the past few years some 15,000 acres of land, most of it in farms in Camden, Burlington, Mercer and Gloucester Counties, have been assembled by builders, on which they plan to construct 50,000 new dwellings. Public housing units, private apartment buildings and thousands of individual homes all have added to the change in the Delaware Basin's living area.

2-02. LAND USE AND SOILS

The recent as well as the expected growth of the population in the Basin is necessitating a re-evaluation of many subjects pertaining to its resources. One of these subjects is the present use of land for producing food and the probable demands that will be made for agricultural land in the future. With a growing population, the Basin and the Nation can look forward to an increasing demand for food. This means that the present ability to produce agricultural surpluses may be lost at some time in the not too distant future. If this happens, cropland and grazing land must be made to yield more products per acre with minimum year-to-year fluctuations, unless radically new methods of producing foods are devised. On the other hand, the added population must live in houses; it must have play space and work space. New factories, stores, parks, playgrounds, streets, airports, parking lots and other nonagricultural facilities must be provided. These, too, require space. Yet the total supply of land cannot be increased. The land area of the Delaware Basin can accommodate a much larger population and provide for the maintenance of the better farming areas which produce the bulk of the farm products. Large areas of relatively low value land could be used for housing and industrial sites.

The land and the conditions under which it can be used vary widely within the Delaware River Basin. Such factors as type of soil, depth of soil, slope of the surface and climate exert definite effects upon the agricultural productivity of the land.

Land has four major types of use: as cropland, as pasture, as forest and woodland, and as sites for nonagricultural activities. The food is derived, of course, almost entirely from cropland and pasture land. Specialized recreational land uses, which are important in highly urbanized areas, usually are included in acreages of forest and woodlands. Urban land use is included in the fourth category.

Agriculturally, the Delaware Basin may be described as neither predominantly rich nor poor. It has some very productive soils, some very poor, and a great many that are median. It possesses the typically flat, sandy lands of the Coastal Plain, the loams and silts of the Piedmont region, and stony loams of the hilly and mountainous portion and a few fertile river valleys. One of the outstanding characteristics of the Basin, agriculturally, is its diversified crop and livestock production. It has grown in the past, and still grows, a wide variety of

crops. Its agriculture has been influenced not only by soils and climate, but by the racial and cultural backgrounds of the people who own and work the land.

2-03. AGRICULTURAL MARKETS AND LAND USES

Another important influence on its agricultural diversity is the fact that the Basin is contiguous to the greatest consumption and export markets in the world. Most of the people in the Basin are consumers of agricultural products, not producers. They consume farm products from every state. But to the fortunate group who live and produce close enough to enjoy a low transportation charge, the "strictly fresh" price is a great inducement in planning and marketing. It makes cash marketing dominant and cash farming the accepted practice. Consequently, as one might expect, intensive farming is practiced wherever the soil is suitable. A considerable acreage has reverted to brush and rough pasture. As in other areas in the Northeast, almost every county in the Basin has experienced a decline in farmland acreage during the past fifty years.

2-04. CHANGING LAND USE PATTERNS

Concentrating population within small areas intensifies the need for riverside wharves and docks, for truck and rail terminals, for fresh water and for waste disposal. Intensive development along the floodplains increases the incidence and the magnitude of financial losses and human suffering if and when floods occur. This development and the conversion of land from agricultural uses adds to the problems of natural resource management. Urban developments with their roofs and paved areas increase the volume and velocity of runoff; thereby contributing to the flood hazard, reducing infiltration and serving to decrease the ground water recharge.

In the hilly and mountainous areas, the drift away from farming, the reversion of fields to woodland and the rising recreational and water supply values of the resulting timbered areas attest to the renewed importance of the forest as part of a sound management program for a drainage area or stream basin.

What will be the future trends in respect to the loss of cropland to nonagricultural uses? It seems apparent that the problem of land withdrawal from agriculture is an important part of the planning for the resources of the Basin. It is only reasonable to expect that, with the continued rapid growth of suburban developments, superhighways and industrial expansion, the withdrawal of land from agricultural use will continue and accelerate. The kind of land withdrawn will affect the agricultural economy of the Basin.

Nearby farmers are caught in the web of these changes. They welcome the increased markets and the sustaining effect on prices received for

their products. Less welcome are increasing production costs from higher wages, higher taxes, higher costs for materials. Farmers also feel the squeeze from changing urban consuming habits, new processing techniques and intensifying regional competition. They recognize that they must change with the times if they are to stay in business. They cannot hope to maintain an extensive use of land in view of competition from more intensive users. Some can improve their production techniques to meet competition from more distant producers. Some realize that their inefficient farms are doomed. Some will be unable to adjust their practices to meet new conditions and to make adequate farm returns. However, with proper planning, large areas of productive land will remain in cropland, pasture and forest cover for generations to come in the Delaware Basin.

Rising values have brought profits and security to owners of land taken for the new homes, factories and communicating highways. Rising demand for level, well-drained lands, on the other hand, has intensified the movement away from agriculture. In some cases, farmers now use less productive lands.

Although many of a modern farmer's decisions are determined by off-farm features, such as location of markets, transportation and price -- the kind and quality of his soils, adequacy of rainfall, temperature ranges and other on-farm conditions greatly influence his choice of enterprise.

SECTION III - TOPOGRAPHY

3-01. PHYSIOGRAPHY

Five of the principal physiographic provinces of eastern United States are represented in the Delaware River Basin. The river rises on the western slopes of the Catskill Mountains and for the first third of its course, flows through the deeply dissected Allegheny Plateau. Local topography was generally moderated by glacial action.

From Port Jervis to Kittatinny Mountain Ridge at the Water Gap, the Delaware River flows through the Appalachian ridges and valleys, a strongly folded section dominated by high parallel mountains separated by relatively narrow valleys. These ridges and valleys generally extend northeast-southwest.

Between Water Gap and the mouth of the Lehigh River at Easton, Pennsylvania, the Delaware flows through an area of rolling hills underlaid by limestone and slate, known as the Taconic Deformation Belt.

From Easton to the head of tidewater at Trenton, New Jersey, the river pierces the Atlantic Highlands, where it has cut through

successively irregular ridges and hills of granite, red sandstone and trap rocks. In this section occurs the southern boundary of glacial influence. Below Trenton, the topography is generally flat or slightly rolling, typically that of the Atlantic Coastal Plain.

The Soil Conservation Service, in its survey of the Delaware River in 1949-50, divided the Basin into three sections referred to as the Upland, Piedmont and Coastal Plain. The Upland section, representing 46 percent of the total drainage area, includes the steeper slopes and mountainous portions of the watershed and embraces all of the New York State portion of the Basin, part of two counties in New Jersey, and all or parts of seven counties in Pennsylvania.

The Piedmont section includes the generally rolling to hilly intermediate portion of the Basin and represents 31 percent of the total drainage area. Slopes are generally shorter and less abrupt than in the Upland. Drainage patterns in the limestone areas tend to be indistinct. All or parts of four counties in New Jersey, nine in Pennsylvania, and one in Delaware are represented in the Piedmont section.

The remaining 23 percent of the Basin area is contained in the Coastal Plain section which has elevations ranging from sea level to 300 feet and gently rolling or nearly level topography. Included in the area are all or parts of nine counties in New Jersey, four in Pennsylvania, and three in Delaware.

SECTION IV - SOILS AND COVER

4-01. SOILS

Approximately half of the Basin was influenced by glacial action. Many of the glacial till or outwash deposits are stony and are adapted to forest cover only. Many glacial tills are shallow, or poorly drained. These factors help to account for the high percentage of land in the upper watershed devoted to trees and grass. Also, the soils in this portion are by nature only moderately productive.

Portions of the Piedmont section contain soils of high productivity. These areas are intensively farmed, as are other areas similarly close to market, but they contain less productive soils.

The Coastal Plain soils are easily worked and managed and are, therefore, largely adapted to the production of vegetables or other intensively grown crops. Some of the Coastal Plain soils are too coarse textured and droughty for agriculture without irrigation. Other soils have poor natural drainage conditions and, consequently, are limited in their adaptability and productivity for modern cropping programs.

4-02. COVER

Some 49 percent of the total watershed area is in forest cover and

41 percent is openland, exclusive of roads, urban and industrial sites. Dairy, poultry and vegetable farming dominate the agriculture; however, there are many other types of production and specialty crops are numerous. Except for those areas where physical limitations cannot be economically removed, the watershed soils can be made to produce satisfactorily when skillfully managed.

SECTION V - FORESTS

5-01. USE HISTORY

Man has used and abused the forests of the Delaware Basin since occupancy began. Aboriginal users created little change in the natural cover, caused practically no lasting damage to soil resources and generally lived within the natural limits of the plant-animal cycle. The Basin was densely forested with fine stands of timber when the first white men arrived. These forests probably provided the optimum condition for natural control of water run-off and soil erosion.

The forests were in the way and a hindrance to the development or transfer of European cultures to the New World. Consequently, the new settlers cleared away and burned much of the forest to make way for homes and farms. As settlement increased, the need for building materials grew, and by 1910 most of the Basin had been cut over for lumber and other forest products. Much of the forest was clear-cut and the cutting was often followed by devastating fires. Following the original cut, immature stands have been repeatedly culled over for mine props, charcoal, chemical wood and other small products. In the anthracite region, many areas have been denuded by stripmining operations. In more recent years, there has been considerable farm abandonment on the steep, eroded lands in the Upland area of the Basin, and the cleared lands have been allowed to revert to brushy forest or more often simply to stand idle.

5-02. FOREST CONDITIONS

A wide range of forest types is found in the Basin due to the variety in climate, topography and soils. The types range from spruce and northern hardwoods in the Upland area to southern pines in the Coastal Plain area. However, the oak types are most common and occupy 40 percent of the forested area, principally in the middle and lower Basin.

Despite all of man's encroachment and misuse, forests still occupy approximately one-half the land area of the Basin. A large portion of the forest area is in young age classes and, as a whole, the stands are understocked. Seedling, sapling and very poorly stocked stands make up 35 percent of the forested area; 40 percent is in pole size stands and only 25 percent of the area in stands of sawtimber size. In addition, the repeated cuttings and frequent fires have resulted in extensive

areas of low value forest types which now present a major management problem. The scrub oak areas, in the anthracite region of Pennsylvania and in sections of New Jersey, are examples of the more difficult areas in need of improvement.

Some of the stripmined areas and abandoned farms are being slowly reforested by natural regrowth and, if properly managed and protected, can again support productive forests. However, much of this land is still denuded or, at best, is becoming overgrown with low value species. Artificial reforestation is necessary to hasten the recovery process and to improve stand composition.

The preponderance of young, understocked stands is reflected in the hydrologic condition of the forest lands. Their present ability to retard run-off is well below what might be attained with a reasonable level of management; though it is probably somewhat better than it was thirty years or more ago. Approximately 10 percent of the forest land is estimated to be in "good" hydrologic condition, 40 percent is "fair" and the remaining 50 percent is "poor."

5-03. PRESENT AND FUTURE USES

Of the present timber cut within the Basin, approximately 80 percent goes into lumber and pulpwood; another 10 percent goes into mine timbers and fuel wood; the remaining 10 percent for poles, posts, piling, cooperage, baskets and miscellaneous products. Utilization of present stands is complicated by the large volume of low grade material contained in them. A major management problem is the development of uses and markets for this low grade material in order that it may be removed and conditions developed for the production of high quality products in future stands.

From the standpoint of numbers of people affected, the forest lands make their greatest contribution by creating opportunities for many forms of recreational use, including hunting and fishing, and by protecting and controlling the flow of water. As populations increase and more leisure time becomes available, the demand on the forests for recreation and water control will become more and more insistent. Coordination of these uses with each other and with the necessity for a sustained increase in the yield of forest products will require careful planning and management.

SECTION VI - CLIMATE AND RAINFALL

The Delaware Basin has a wide range of climatic conditions. Lying as it does, partly southern and partly northern, it has important features from both. Added to this are the effects of a range in elevation from sea level to over 3,000 feet, its proximity to the tempering influences of bay and coastal waters, and the wide variations in length of growing season (100 to 200 days) and the ranges in mean temperature and

rainfall are easily understood. The distribution of mean annual rainfall is illustrated in Figure 1.

For the most part, the climate of the Delaware Basin Uplands can be classed as cool and moist. This part of the watershed is primarily in forests. It is also a recreational area of great magnitude, popularity and potential. Its limited agriculture depends largely on dairy production, since the climate favors grass, but normally permits silage corn production.

Climate of the Piedmont and Coastal Plain areas is considerably more mild in winter and warmer in summer. Growing seasons are appreciably longer and hot. The combination of lighter soils, higher temperatures and greater air movement increase evaporation and transpiration rates, and drought conditions of varying severity occur almost annually somewhere in the Basin.

The Delaware Basin is subject to many of the cyclonic disturbances that cross continental United States. Stagnant warm fronts often result in Basin-wide floods. The more usual cold front passing over the area may cause flooding of small tributary watersheds; a series of these storms may produce dangerous conditions on several small watersheds but do not pose a serious flood threat unless there is also present a heavy snow cover. Widespread flooding usually has been the result either of tropical disturbances that have moved up the East Coast, or coastal cyclonic developments on slow-moving cold fronts.

Tropical hurricanes are relatively infrequent in the Delaware Basin. However, it was the remnants of such a storm that produced the record breaking flood of August 1955.

PART B - FARMING

SECTION I - INTRODUCTION

The pattern of agricultural production in eastern United States has been characterized by almost constant change since the country was first settled. First families chose what were considered to be the best sites; late comers and following generations took what was left or moved to other frontiers. The original subsistance type of general farming fell before the economic pressures of a developing commercial economy. New producing areas in distant regions created new competition for products that shipped well, but the increasing urban population, due to the rise of industrialization and world trade, created new markets in perishables for nearby farmers. Caught between these economic forces some families on marginal farms abandoned their holdings and moved away or into other activities. Those who remained changed their farming pattern to meet the situation.

Spatial requirements for agricultural use expand and contract in response to demand for agricultural products and the economics of production. Technological improvements in production methods, changing dietary habits, wars, public policies and the effect of many other factors are reflected in diverse ways by the agricultural pattern of any community.

Study of trends in land use, livestock numbers and farm management takes into account the effect of past changes and provides certain limited guides to probable future adjustments. It is necessary to know the present pattern before a new pattern can be plotted. This paper presents statistical data and descriptive material on agriculture as it has existed in the recent past within the Delaware Basin.

The Delaware River Basin is approximately 260 miles long and has a maximum width of 75 miles. The Delaware drains 12,765 square miles -- 2,969 are in New Jersey, 2,362 in New York, 6,422 in Pennsylvania, 1,004 in Delaware and 8 in Maryland.

Included within this area are all or nearly all of 27 counties and fractional parts of 15 others. The Soil Conservation Service estimated that 49 percent of the entire watershed was openland, 45 percent was woodland and about 6 percent was in roads, urban areas, streams and lakes in 1950. The proportion of openland has declined and that of nonfarm uses has increased since that date.

The United States Census of Agriculture for 1954, providing statistics on a county basis, is utilized for much of the statistical description of current agriculture. These data will be at variance with estimates calculated on other bases since information for fractional counties

was not gathered. The counties included in the analysis are listed in Appendix Table 5.

SECTION II - LAND USE AND CROPS

2-01. MAJOR USES OF LAND

The Bureau of the Census reports 9,987,840 acres in the 27 counties lying predominantly within the Delaware Basin (Table 1). Of this area, 4.7 million acres, or 47 percent, were included in 45,911 farms in 1954. From 1940 to 1954 the number of farms in the Delaware Basin decreased by nearly 25 percent and land in farms decreased about 13 percent. These adjustments, however, affected the acreage harvested by only 4 percent. Average size of farm increased from 89 acres in 1940 to 102 in 1954 and average cropland harvested per farm rose from 37 to 47 acres (Table 2).

Woodland and recreation predominate as nonfarm land uses in the highlands of the Upper Delaware Basin. For example, only 26 percent of Sullivan County, New York, 11 percent of Pike County, 20 percent of Monroe County and 22 percent of Carbon County, Pennsylvania, respectively, are in farms (Fig. 2). Tillage practices in these counties are limited largely to long rotations based on grassland farming with small acreages of grain, corn silage and a few small areas where certain vegetables are grown for special markets.

In the middle reaches are found dairying, specialized vegetables, a few commercial orchards and poultry. In this sector also are found numerous industrial towns and cities with their accompanying needs for transportation routes and suburban developments. However, even urbanized Philadelphia County has 6 percent of its area classed as farmland. In parts of other counties are found estates which pass as farms, intermingled with agricultural units whose owners have no other sources of income. Among these, Delaware County, Pennsylvania, with 26 percent of its land in farms, is an example. The remainder, lying further from major industrial centers and containing lands suitable for intensive culture, tend to have larger portions of their area in agriculture. For example, in Northampton, Berks and Lehigh Counties, respectively, 62, 63 and 65 percent of land area is in farms.

In the Coastal Plain area, dairying tends to disappear due to forage production problems and to more satisfactory alternatives in specialized poultry, truck crops and cash grains. Competition from industry for labor is strong throughout the region.

TABLE 1. LAND USE, 1954 1/
DELAWARE RIVER BASIN

Land Use	27-County Area	
	Acres	Percent
Land Not In Farms	5,302,466	53
Land In Farms	4,685,374	47
Total Land Area	9,987,840	100
Cropland Harvested	2,165,387	46
Cropland Pastured Only	371,836	8
Cropland Idle	232,613	5
Woodland Pastured	221,385	5
Woodland Not Pastured	820,674	17
Farmsteads, Roads, Waste, etc.	873,479	19
Total Land In Farms	4,685,374	100

1/ From 1954 Census of Agriculture.

TABLE 2. SIGNIFICANT TRENDS IN AGRICULTURAL LAND USE, 1940-54 1/
DELAWARE RIVER BASIN

Item	1940	1950	1954
Number Of Farms	60,552	52,500	45,911
Acreage In Farms (000)	5,404	5,008	4,685
Cropland Acreage Harvested(000)	2,249	2,182	2,165
Average Acreage Per Farm	89	95	102
Average Cropland Harvested Per Farm	37	42	47

1/ Census of Agriculture. Data are for 27 counties.

It is difficult for many persons to realize the general low intensity of land use existing in this region of bustling urban and industrial activity. In all, 8 of the 27 counties have from 6 to 30 percent of their areas in farms, 9 have from 31 to 60 percent and 10 have from 61 to 70 percent.

The small proportions of total area that are being cropped is even more startling. In Pike County, Pennsylvania, only 1.6 percent of the land area was in harvested cropland during 1954. In 7 of the 27 counties, cropland harvested was less than 10 percent of their area. In only two, Northampton and Lehigh, was the proportion over 40 percent. (Fig. 3).

Shifts that have occurred in the distribution of cropland harvested during the 15-year period 1939-54 can be explained. The decline occurring in farms having fewer than 50 acres of harvested cropland was almost inevitable in view of changing technology and the local, national and international situation. Conversely, the proportions of farmers reporting 50 or more acres harvested has increased as might have been predicted (Table 3).

Greatest declines in cropland acreage reported occurred in Philadelphia and Delaware Counties, Pennsylvania, where urbanization has taken place and alternative employment opportunities have been attractive (Fig. 4). The effect of these same pressures has been felt to a lesser extent in New Castle County, Delaware, in Chester, Montgomery and Bucks Counties, Pennsylvania, and in Camden and Burlington Counties in New Jersey.

Drastic reductions in cropland acreages harvested have occurred in the rougher sectors of the Basin. These lie in the belt encompassed by the Allegheny Plateau and Northern Piedmont Smallscale Dairy and General Farming areas. High costs of production, inability to mechanize, scarcity of labor and plentiful opportunities for profitable, nonfarm work have encouraged a greater incidence of cropland abandonment here than in areas better suited to agriculture.

TABLE 3. DISTRIBUTION OF CROPLAND HARVESTED BY NUMBER OF FARMS, 1944, 1949, AND 1954
DELAWARE RIVER BASIN

Acreage Harvested Per Farm	Distribution Of Farms With Harvested Cropland 1944 1/		1949		1954	
	Number	Percent	Number	Percent	Number	Percent
None	2/	3/	8,117	15	7,650	17
1 to 9	12,742		9,532	18	7,438	16
10 to 19	7,300		5,942	11	4,489	10
20 to 29	5,711		4,669	9	3,794	8
30 to 49	9,941		8,138	16	6,697	14
50 to 99	13,625		11,045	21	10,110	22
100 to 199	4,806		4,127	8	4,514	10
200 and over	836		930	2	1,219	3
Total	54,961 3/		52,500	100	45,911	100

1/ Comparable data for 1939 not available.
2/ Not available.
3/ The number of farms with no cropland harvested in 1944 was not tabulated. Therefore, percentage distribution cannot be calculated for this year and the total number of farms is understated by this amount.

Cropland harvested in the 8 Coastal Plain counties increased an average of 7 percent during the 15 years. If Burlington and Camden are eliminated, due to their urban features, the acreage increase is nearly 53,000 acres, or 10 percent more than was harvested in 1939.

In 10 of the 27 counties the cropland harvested has changed less than 5 percent in the 15 years. For all practical purposes, this probably can be considered as no material change. In another 10, the change ranged between plus or minus 5 to 10 percent and in the remaining 7 the change was 10 percent or more.

Of all land in Delaware Basin farms in 1954, about 59 percent was classified as cropland (46 percent harvested, 8 percent used only as pasture and 5 percent idle, i.e., not harvested and pastured). The remaining 41 percent of land in farms includes woods pastured (5 percent) and unpastured (17 percent), farmsteads, wasteland, roads, etc. (19 percent). While the proportionate use of lands will vary widely from area to area within the region, there are relatively few sections that have no serious limitations on agricultural uses due to poor soils, rough topography, or poor drainage.

A reviewer from New Jersey stressed recreational aspects of land use for his state, but also for much of the Basin, as follows:

"The one point I should like to make is that the recreational potential of these farmlands is scarcely touched. They do constitute one of the most important areas for small game hunting and deer hunting in this state.

"There has also been a tremendous increase in farm fish ponds ... These ponds, besides furnishing waterfowl breeding areas and local fishing, have a high value for irrigation and fire protection.

"Most of New Jersey's better trout waters flow through this area and soil conservation practices and other farm use trends affect the quality of water in these streams, while much of the recreational enjoyment of the fishing is had on privately-owned farmland."

Crops were harvested from 2,165,000 acres in 1954. A statistical average of 47 acres harvested per farm, however, adds little to an understanding of farm problems or the future needs for supplemental water. Seventeen percent of all farmers enumerated reported no cropland harvested and another 16 percent reported less than 10 acres. Fifty-one percent of the holdings contained less than 30 acres of harvested cropland per farm.

The most frequent class or type of "farms" by Census definition least dependent on cropland are the smallscale general farmers. For example, 30 percent of the farmers in Pike County, Pennsylvania, depend

heavily on recreation and summer camp activities for their support. These are followed by the poultry farmers of northern New Jersey who account for 25 percent of all farms in their counties and the small-scale poultry and retired or rural estate farmers who account for 24 percent of the farms in Delaware County, Pennsylvania. Sixty percent of the farmers in Delaware County, Pennsylvania, reported less than 10 acres of cropland harvested in 1954.

2-02. MAJOR CROPS GROWN

Climatically, the Delaware Basin is a borderland. Lying as it does, neither north nor south, it has important features from both. In the same way, by stretching from the seashore to the mountaintops, it provides great climatic variation due to elevation. Therefore, averages, or even ranges of temperatures and length of growing season, mean very little. The growing season ranges in length from nearly 200 days in southern coastal sections to approximately 100 days in the high elevations of the headwater areas. The wide range in temperature and rainfall conditions, the variety of adapted crops and the erratic market cause a cropping pattern both flexible and involved. Currently, cash grains like corn and soybeans are increasingly important in sections which were specialized producers of canning crops only a few years ago. A mushroom industry is centered where formerly dairying flourished. Truck crops for fresh market are being grown on former bogs. Beef cattle are grazing on some of the best meadows.

Cropland use in the Delaware Basin fluctuates within wide limits, depending upon economic conditions. A long-term, downward trend was slowed by the Depression of the 1930's and was reversed sharply by demands from the wartime economy of the 1940's. Post-war conditions of full employment, relief to foreign nations and continued production controls have decelerated but not halted downward adjustments in land used for crops.

The magnitude of adjustments made within the short span of 10 years, 1944-54, together with some of the economic reasons for these changes, will provide guides to further adjustments. Although total cropland harvested declined 15 percent during the period (Table 4), use of additional fertilizer and lime, better crop varieties, better cultural practices and new techniques often resulted in maintained or increased crop yields. Better breeding and better feeding, in turn, resulted in higher returns from livestock and poultry.

Large portions of cropland in the Basin are rolling to rough and must be utilized as grasslands. Hay was cut from 772,346 acres or from about 36 percent of all cropland harvested in 1954 (Table 4). Although the acreage had declined about 9 percent in 10 years, an increase of 0.2 to 0.3 ton in yield per acre helped maintain volume. Better management helped to improve quality of forage production.

TABLE 4. ACREAGES OF MAJOR CROPS HARVESTED, 1944, 1949 AND 1954 DELAWARE RIVER BASIN

Crop	Acreage Harvested 1944	1949	1954	1954 Compared With 1944
	Acres	Acres	Acres	Percent
Hay	846,145	769,783	772,346	91
Corn	567,829	609,599	578,945	102
Wheat	279,769	264,157	182,352	65
Vegetables	227,629	186,060	183,070	80
Oats	174,595	131,383	150,402	86
Soybeans	130,899	115,993	134,367	103
Barley	45,332	71,785	77,788	172
Orchards	63,529	52,805	40,227	63
Irish Potatoes	77,896	48,652	35,483	46
Berries for sale 1/	7,382	5,127	9,104	123
Total Cropland Harvested 2/	2,534,688	2,182,197	2,165,387	85

1/ Excludes cranberries in New Jersey.
2/ These totals include crops other than those listed above and also have been adjusted for acreages double-cropped.

Corn, the second most common crop grown, and soybeans have been maintained at relatively high levels of production as cash crops. Smaller labor requirements than for some other crops, improved varieties, better yields, new harvesting equipment and good prices have encouraged many farmers to expand their acreages of these crops. Conversely, wheat and oat acreages have declined. Barley acreage has been expanded in areas where it is adapted as an adjustment in post-war land uses. Barley yields have improved considerably. It usually will produce more feeding value per acre than oats in these sections and can be grown where corn is unprofitable.

Acreages of commercial vegetables were 20 percent less than they were only 10 years previously. A continued downward trend in their importance probably will occur for the Delaware Basin as a whole. Labor-intensive crops which are not adaptable to mechanization are disappearing in counties most affected by the new surge of industrialization. Crops with high labor costs and yields low, relative to those of other areas, also are declining as farmers adjust production schedules to meet changing conditions.

The problems mentioned above have been joined by the alienation of cropland for urban and industrial purposes in Bucks, Montgomery, Philadelphia Counties, Pennsylvania; Camden, Burlington, Mercer, and to some extent in Hunterdon Counties, New Jersey. New Castle County, Delaware, has had a surge of urbanization, but this activity generally was not in the vegetable producing section.

Production of vegetables apparently has been forced further afield by urbanization as demonstrated by the increased acreages in the secondary belt of counties represented by Kent County, Delaware; Salem, Gloucester and Cumberland Counties, New Jersey; and Berks, Chester and Schuylkill Counties in Pennsylvania.

Location between the early southern production areas and the later northern areas has pinched Basin producers on price and markets. The first flush of high prices for fruits and vegetables usually is past before Basin producers can reach the market. On the other hand, high prices are realized periodically when drouth, frost, or other unseasonable conditions cause a shortage on eastern markets at marketing time. Irish potatoes, tomatoes, sweetcorn, green vegetables and similar seasonal crops are in this market squeeze category.

The trend in orchards, small fruits and berries has been sharply downward. Cranberry acreage in New Jersey has declined nearly 50 percent since 1949. 1/ The acreage in orchards has declined 24 percent since 1949 and 37 percent since 1944. Again, these trends are caused by low yields, diseases, high production costs and severe competition from other orchard areas. The only fruit crop showing a significant increase is tame blueberries in Burlington County, New Jersey, where over 1,000 acres were established between 1949 and 1954.

2-03. CROP YIELDS

Average crop yields for an area having conditions so variable as those of the Delaware Basin would mean little. In general, the trend has been slightly upward. Few crops have shown startling improvements in yields for any area. Indicative yield data for four counties believed to represent larger areas are shown in Appendix Tables 1, 2, 3 and 4.

2-04. IRRIGATION

Prior to the close of World War II irrigation had no popular following in the Delaware Basin. This practice was known to be needed in the arid West but was followed locally only by a few specialized market gardeners, florists, cranberry growers - and for watering lawns. Prolonged drouths were relatively uncommon and short drouths were an accepted risk to be borne.

Numerous studies of irrigated pasture and forage enterprises have developed conflicting reports on the economic value of this practice. Further study with better controls and better definition of conditions is necessary before adequate guides are available. Generally, it would appear now that purchase of irrigation equipment for forage and pasture production alone will pay only under exceptional circumstances. On the other hand, if a farmer already has the equipment for some other purpose and has the water available, it often would pay to irrigate pastures and hayland rather than to have the equipment lie idle and the water unutilized. There appears to be little question that irrigation pays for high value truck crops and orchards throughout intensive farming areas of the Basin.

1/ The Statistician in Charge (AMS) at Trenton wrote, "In 1956 we conducted a complete enumeration of all known cranberry growers in the State. For Burlington County, this survey shows a total of 3,321 acres of cranberries of which 533 acres received no care, 459 acres are not yet bearing, 250 acres were 'late held' under water and 2,079 acres were in production. For comparison with the 1949 Census total of 5,350 acres, I believe that the 3,321 acres in 1956 would be most comparable. For Cumberland County the survey includes a report for only one grower with no acreage receiving care and only a few acres harvested."

Improving technological knowledge of crop requirements for optimum growth and physical characteristics of soils, increasing use of concentrated fertilizers, pressures for increased yields per unit of production and the startling results of experiments with irrigation have popularized this practice during the 1950's. The acreage irrigated pyramided due partly to the incidence of dry seasons and also to development of lightweight pipe and better equipment. A study was conducted jointly by the Census Bureau and Agricultural Research Service in 1955 to assess the current irrigation situation in the humid eastern United States. A separate analysis of data for Delaware Basin counties is being made as a portion of the Basin Studies series.

SECTION III - LIVESTOCK AND LIVESTOCK PRODUCTS

3-01. DAIRY

In April 1955 there were in the Delaware Basin 397,131 cows and heifers that had calved at least once. Ninety-five percent of these were dairy cows. Although several nationally known beef-type herds are found in this region, beef production does not loom large in the agricultural industry.

Nearly 2.5 billion pounds of whole milk were sold from these dairy herds during 1954. Dairying fits well with the topography, soils and climate of most of the Basin. Nearby urban areas provide a large market. Competition is severe from other producing areas in New York, Pennsylvania, New England and even the Midwest. As a consequence, many small, inefficient dairy farms are unable to provide necessary levels of living for the farm families and even the better organized farms are hard pressed to show satisfactory profits.

The small, poorly organized dairy farm appears to be doomed in the future. Their operators must intensify management, expand operations and reduce costs to stay in business. Otherwise, the buildings will be used for nonfarm purposes or become idle, and the cropland will revert to forest if it cannot be integrated advantageously into the organization of nearby farms. Farms in areas of urban expansion will be used as sites for industry or housing development.

3-02. HOGS

Although the Delaware Basin is not considered to be a pork producing area, a quarter million hogs and pigs were raised and sold from the Basin in 1954. They came from more than 45 thousand farrowings. The average of 5.5 animals sold per farrowing does not represent total production, however, because an appreciable number are raised and butchered for home consumption. While the hog enterprise

seldom is of major importance in the Basin, it does constitute a rewarding small, supplemental enterprise on farms where surplus corn is available. Thus, Sussex County, Delaware, with its 5,000 farrowings and over 25,000 hogs and pigs sold, or Berke County, Pennsylvania, with more than 4,100 farrowings and over 20,000 sales, are strong producers of corn for grain. Gloucester, Burlington and Hunterdon Counties in New Jersey, which account for nearly 100,000 hogs sold alive in 1954, also rank high in production of corn for grain.

In this metropolitan area are found numerous garbage feeding establishments. Relatively few hogs are found on the specialized dairy, poultry, or truck farms of the region. These are raised primarily for family use.

3-03. SHEEP

Sheep production has declined in the East, generally, over the years. Flocks now are kept on estates or are relegated to the hill farms where a combination of circumstances prevent use of the land for dairy production. Berks, Chester, Montgomery and Bucks Counties in Pennsylvania, and Hunterdon and Warren Counties in New Jersey, are the major sheep producers, although every county in the Basin has one or more flocks. One reviewer believes that the number of sheep on Basin farms has increased since 1954, but the increase probably is relative only. We have no comprehensive statistics to warrant belief that the increase is truly significant.

About 31,000 sheep and lambs were shorn in this 27-county region during 1954. The average fleece weighs between 6.5 and 7 pounds. Although wool is an important by-product, the commercial flock owners depend on sale of early lambs to the nearby Eastern markets. About five sheep and lambs were sold for every six sheep on farms in 1954. Modern marketing and transportation techniques and changing dietary habits of consumers have made specialized sheep enterprises marginal in much of the region.

3-04. POULTRY

Poultry is big business in parts of the Delaware Basin. Over 12.2 million chickens four months old and over, primarily laying hens, produced 122.2 million dozen eggs in 1954. Small farm flocks are scattered generally throughout the region, but specialized production is concentrated in a few counties. Cumberland County, New Jersey, alone, had 20 percent of the laying hens and produced 21 percent of the eggs. Cumberland, Salem and Gloucester, which comprise the South Jersey poultry area, had 21 percent of the hens and produced 32 percent of the eggs sold. These data represent practically a 50 percent increase for these counties in 5 years. North of Philadelphia and Camden, Hunterdon County, New Jersey, had 1.4 million birds; Berks and Bucks Counties, Pennsylvania,

each had about 800,000; and Sullivan County, New York had over 833,400. Eggs from these flocks are consumed in nearby Eastern markets.

Broiler production has developed rapidly as a major industry during the past 15 years. From an almost insignificant beginning in Sussex County, Delaware, it has grown to become a major type of farming. The 27 Basin counties studied produced over 74 million broilers in 1954. Sussex County alone produced 78 percent of the region's broilers; Kent County added another 5 percent.

The remaining 13 million birds were produced in three much less intensive areas, or in isolated flocks. Most significant in numbers of birds produced is the northern sector, including Sullivan and Delaware Counties, New York, and Pike and Wayne Counties, Pennsylvania. Each state produced two million birds.

The third significant area (Camden, Gloucester, Cumberland, Salem and Burlington Counties, New Jersey), which produced 3.6 million birds, can hardly be compared with the Sussex-Kent, Delaware area. Although Camden County produced 1.3 million birds and Gloucester 1.0 million, interest in broilers always has been overshadowed by the egg industry.

Berks, Chester and Schuylkill Counties, Pennsylvania, combined, produced another 3.1 million birds. This development is an offshoot of a small, specialized broiler area which developed in and near Lancaster County toward the end of World War II.

SECTION IV - INCOME AND LEVELS OF LIVING

4-01. FARM INCOME

More than 7 of every 10 farms in the Delaware Basin are classed as commercial by the Census of Agriculture. Residential and part-time units comprise the remainder (Table 5). One of every 16 commercial farmers sold between $250 and $1,199 of farm products in 1954; one of every five sold less than $2,500 worth. At the other extreme of the scale, one farmer in every twelve sold $25,000 or more; one in three sold $10,000 or more; and about every second commercial farmer's income ranged between $2,500 and $10,000. Delaware Basin agriculture is dominated by relatively small farms.

4-02. SALES OF FARM PRODUCTS

Farm product sales in 1954 amounted to $396,500,637 (Table 6). Livestock and livestock products accounted for over 65 percent of the total, all cultivated crops for 34 percent, and forest products for less than 1 percent. Milk, eggs and poultry meat account for more of the Basin's agricultural income than all other products combined. Intensive cash crops, including commercial vegetables, fruits, nuts and

TABLE 5. ECONOMIC CLASS OF FARMS, 1954
DELAWARE RIVER BASIN COUNTIES

Economic Class Of Farm	Value Of Products Sold	Farms	Commercial	All Farms
	Dollars	Number	Percent	Percent
Commercial		33,676	100	73
Class I	25,000 or more	2,697	8	6
Class II	10,000 to 24,999	9,130	27	20
Class III	5,000 to 9,999	8,725	26	19
Class IV	2,500 to 4,999	6,467	19	14
Class V	1,200 to 2,499	4,671	14	10
Class VI	250 to 1,199	1,976	6	4
Other Farms		12,235		27
Part-time		5,298		12
Residential		6,872		15
Abnormal		65		-
Total Farms		45,911		100

TABLE 6. VALUE OF FARM PRODUCTS SOLD, 1954
DELAWARE RIVER BASIN FARMS

Produce	Value
	Dollars
All Crops	134,910,464
All Livestock And Livestock Products	260,611,471
Forest Products	978,702
Total Value Of Products Sold	396,500,637

horticultural specialties have been declining in importance. In combination, they account for slightly more than 20 percent of farm sales. Field crops grown for sale have been increasing in importance during recent years. Sales of corn and soybeans have increased significantly while wheat, oats and barley sales are up slightly in some areas and down in others. Subsidy policy on wheat has helped to maintain this crop. Oats and barley are traded locally as feed grains.

Forest products, bringing in less than a million dollars in the 27 counties during 1954, obviously do not bulk large as a farm enterprise. The importance of forest industries in the Basin is considerably greater than is shown, however, because of the nonfarm lumbering, pulpwood, Christmas tree and recreational enterprises based on nonfarm forests.

Cash farm income per acre of cropland ranges from a low of $93 in Carbon County, Pennsylvania, where 56 percent of all farms in 1954 were classed as noncommercial and 60 percent of the commercial farms provided incomes of less than $5,000 during the year, to $421 in Pike County, where 2 out of 3 farms were classed as commercial and 2 out of 3 commercial farms were classed as poultry types. Income per acre is affected by the types or intensity of farm enterprises as well as by soil fertility (Fig. 5). Thus, the returns per acre from the small-scale general and dairy farms normally are considerably lower than are found in areas of intensive vegetables and poultry, which depend upon labor and cash inputs to a greater degree than upon inherent soil productivity.

4-03. FARM TENURE

Farm tenure in the Basin is dominated by owner-operated family-sized farms. Over 90 percent of all farms are controlled by full or part-owners; only 9 percent are rented and less than 1 percent are operated by managers. Renters are located in all counties and farm managers were tabulated for all but Carbon and Pike Counties, Pennsylvania.

Tenancy is least common on the relatively small, general purpose, hill farms and relatively more common in counties where commercial agriculture requires larger farm units, large capital investment and more complicated management.

4-04. FARM OPERATOR FAMILY LEVELS OF LIVING

The Agricultural Marketing Service, and its predecessor in the Bureau of Agricultural Economics, has prepared an historical series of indexes to demonstrate changes in levels of living among families of farm operators. The concept of these indexes is to reflect average levels of current consumption, or utilization of goods and services.

Services are broadly interpreted to include both publicly furnished and privately secured services that contribute to well-being and provide satisfaction. 1/

The United States index of 100 is based on the 1945 average situation. It had increased to 122 by 1950 and to 140 by 1954. All counties in the Delaware Basin rated higher than the United States average in 1954. Carbon and Schuylkill Counties in Pennsylvania, with indexes of 155, were the worst off but even these were 15 points above the United States average. The Basin's median index of 177 indicates that the Basin, generally, has a relatively high level of living. All but 5 rated above the average index of 168 for all counties in the Middle Atlantic States.

Figure 6 shows that most of the counties having the lowest indexes lie along the rough, mountainous backbone of the Basin where farms generally tend to be the smaller and less efficient. Exceptions to this are Camden County in New Jersey, and Kent County in Delaware, where institutional factors apparently make the indexes show an abnormal situation.

Farm families in Basin counties generally have improved their status in relation to the average for Mid-Atlantic States during the past 25 years. Seven of 14 counties below the average index in 1930 were above the average in 1954.

4-05. SIZE OF FARM AND FARM VALUES

Average size of farm in the Basin is 103 acres and the average farm contained about 47 acres of cropland. Size ranged from Camden County's average of 42 acres per farm for its poultry and small truck producers to 210 acres on specialized dairy farms in Delaware County, New York. Modal farm size of 84-85 acres is concentrated in the area of Hunterdon County, New Jersey, and Bucks, Berks and Schuylkill Counties, Pennsylvania. Generally, farm size decreases near urban and industrial areas and increases with distance from these centers. Larger farms usually are associated to some extent with lower quality of land and with distance from markets (Fig. 7). This rule does not always apply, however, because certain enterprises, such as poultry, have little dependence on land area.

1/ Items used in the index formula include (1) percentage of farms with electricity in farm dwelling, (2) percentage of farms with telephone in farm dwelling, (3) percentage of farms with automobiles, and (4) mean value of products sold or traded per farm reporting. See USDA (BAE) Farm-Operator Family Level-of-Living Indexes for Counties of the United States, Washington, May 1952, for methodology and theory.

Average values of land and buildings per farm in the Basin vary widely from a low of $10,262 on the small dairy, poultry and general farms of Schuylkill County to $96,286 on the specialized vegetable farms of Philadelphia County. Seven counties lying along the mountainous backbone of the Basin, together with Sussex County, Delaware, where land values are low and farm buildings are relatively inexpensive, had average values of land buildings of less than $16,000 per farm (Fig. 8). Twelve counties were within the range of $16,000 to $31,999 per farm and seven had average value of $32,000 or more.

Value of land and buildings per acre represents the interaction of several economic forces. Among the most important are the productivity of the soils, the type of farming being followed, competition for the land as reflected in the land market and distance from market. Figure 9 summarizes the value judgments people have placed on land and buildings in the Basin at the time the 1954 Census of Agriculture was taken. Land values in many of the more populous counties undoubtedly have risen appreciably in the interim. Section V, which follows, develops some reasons for these judgments as they are reflected in types of farming.

SECTION V - TYPES OF FARMING AREAS AND TYPICAL FARMS

5-01. DEFINITION OF FARMING TYPES

The authors of a contemporary textbook on regional agriculture in the United States entitled their first chapter: "The Nonexistent 'Typical' American Farm." 1/ Their point is well taken. We, all too often, tend to forget that no two farms are identical in their physical resources, or in the problems they present. No two farmers would organize, operate and manage the same farm in the same way.

However, in almost every farming community there are certain kinds of farming which tend to be most common and there are central tendencies toward certain sizes of dairy herd, poultry flock, or acreage in crops. Production and marketing problems of dairymen versus poultrymen, grain farmers versus truck farmers, or commercial operators versus residential farmers differ greatly in content and detail. Problems of the largescale dairyman and the smallscale operator usually are of the same general nature but differ largely within the economics of scale and managerial ability.

Recent generalized type of farming maps show at least four important farming sub-groups within the Delaware Basin. These are delineated on the basis of most frequent and most significant types of farm business. Farming systems generally have taken their present form in response to physical, economic and biologic forces and conditions.

1/ Haystead and Fite, The Agricultural Regions of the United States, University of Oklahoma Press, 1955.

Propinquity and personal preferences are significant determinants for individual farmers during the short run period, but these often prove to be insupportable in the longer period. Thus, no one tries to grow cotton in eastern Pennsylvania, because everyone recognizes that physical conditions are unsuited to the crop. Conversely, a profitable truck crop enterprise can flourish on several of the available soil types, because the nearby urban market demands these highly perishable crops. Further afield, dairying can utilize rolling grasslands unsuited to row crops and to intensive cultivation.

Physical conditions that affect types of farming usually are climate, topography and types of soils. In the Delaware Basin, the agricultural regions tend to extend east and west following temperature zones, and secondarily north and south with the contours of the terrain. Soils and topography largely determine whether the farming type can be row crops, must be based on grassland, or whether agriculture can be practiced profitably at all.

Economic conditions determine types of farming through comparative returns from the several enterprise alternatives. Prices received for farm products, costs of production, economics of supplementary and complimentary enterprises, seasonal demands for labor, availability and cost of technological improvements and similar factors may rule out, or, conversely, encourage development of fairly common farm types within the same agricultural zone.

Biologic factors are simply additional complications in the farm management complex. Weed, insect, or disease infestations may raise costs of production to the point where an enterprise disappears from a farming area. Red stele disease of strawberries, for example, was a major factor which drove Delmarva farmers from berries to broilers. On the other hand, new varieties and strains of crops or livestock may help to maintain a farming area. Improved forage grasses and legumes are helping eastern dairymen reduce production costs by switching from purchase of expensive shipped-in concentrates to production of high quality hay, silage and pasture (grassland farming). Improvements in soybean varieties have increased yields and uniformity in growth and maturing habits until now soybeans can be grown economically in competition with fresh vegetables and canning crops in some areas.

One generally finds that farm families have developed the types of farming best meeting requirements set by physical and economic conditions of the times. Some situations will exclude all but one type of farming; others will permit major and minor types more or less interspersed.

The influences of urban-industrial pressures on one hand and limited resources on the other cloud our perspective; thirty percent of all

Delaware Basin "farms" according to the Census are noncommercial 1/ and in miscellaneous classifications (Table 7). 2/ Usually, however, there is some modal tendency which can be described and used as a more or less satisfactory "average." It is these modal situations that are used to describe the commercial agriculture now found in the Delaware Basin.

Of the over 32,000 commercial farms, 41 percent were dairy types, 26 percent were poultry, 12 percent were field crop types and the rest were a mixture of vegetable, fruit, livestock other than dairy or poultry, and general types.

5-02. MAJOR TYPE OF FARMING AREAS

The major single type of farming on an area basis involves dairying and various combinations with it. Specialized dairying is practiced almost exclusively in Delaware and Sullivan Counties, New York, in Wayne and parts of Pike Counties, Pennsylvania, and in Sussex, Warren and part of Hunterdon Counties, New Jersey. These lie almost entirely within the Central Northeast Dairy area, (Fig. 9a), where soils, terrain and climate limit cultural practices to long-term rotations, based on hay and pasture with limited acreages of small grains and small amounts of corn silage on the leveler bottom fields. Much of the pasture land is extremely poor and often steep and rocky.

Adjoining the Central Northeast Dairy area is the Northern Piedmont Dairy and General Farming area. Dairying, poultry, fruit and canning crops predominate on these farms. However, some beef herds, flocks of sheep and cash grain farms dot the landscape. With the exception of New Castle County, Delaware, all Delaware Basin counties in this farming type are in Pennsylvania.

Dairying predominates and poultry is second in Berks, Bucks, Chester, Northampton and Montgomery Counties. Other livestock, field crops and general farming types are interspersed among the dairy and poultry farms in all of these counties.

Although Lehigh County is included in the Northern Piedmont Dairy and General Farming area, it tends to have smaller and more diversified farms than do some of its more fortunate neighbors. Nearly half (45 percent) of its farms have fewer than 30 acres of cropland. Even so, the predominant farm type is field crops, followed by poultry, general farms and dairying.

1/ Part-time, rural resident, or abnormal.

2/ Had 50 percent or more of the total value of products accounted for by sale of horticultural crops (nursery stocks, etc.), or sale of horses, or sale of forest products.

TABLE 7. MAJOR TYPES OF FARMS IN 27 COUNTIES, 1954
DELAWARE RIVER BASIN

Type Of Farm	Farms	Commercial	All Farms
	Number	Percent	Percent
Dairy	13,202	41	29
Poultry	8,412	26	18
Field Crop (other than fruit and nut)	3,793	12	8
Vegetable	1,980	6	4
Livestock (other than dairy and poultry)	1,838	6	4
General	2,413	7	5
Fruit And Nut	772	2	2
Miscellaneous And Unclassified	13,511	-	30
Total	45,911	100	100

Agriculture in Philadelphia County is limited to truck farming and to a few general operations. Delaware County also fails to fit any apparent pattern. Due to its suburban location and the large number of estates within it, one finds many fine dairy farms, beef herds, orchards and general farms which are hardly to be compared with the usual working farm. The King Ranch of Texas owns 10,000 acres, rents another 2,000 acres, and operates as a steer finishing station nearby in Chester County. Farming and fox hunting are associated on many places. However, in addition to these unusual circumstances, one finds many other very fine farms. The soils are productive, but generally rough terrain requires careful soil management to prevent erosion.

For our purposes, the Central Pennsylvania Dairy and General Farming subarea and the Allegheny Plateau Smallscale Dairy and General Farming subarea can be combined. Location of the farms in relatively isolated, narrow, mountainous valleys, having very limited areas of good soils, result in a diversified type of small agricultural enterprise. Dairy, beef, or sheep, poultry and field crops for sale (primarily wheat and buckwheat) often are combined on the same farms.

Thus, in Schuylkill, Monroe and Pike Counties poultry farms predominate, but dairying is a close second; while in Carbon County no one type of farm dominates. Small general farms and field crop enterprises are important in this mountainous sector.

The fourth major type of farming section is the Atlantic Sandy Coastal Plain Truck and Mixed Farming area reaching from Long Island to the tip of the Delmarva Peninsula. Truck crops and livestock farming are interspersed depending upon local soil conditions, distance from market and general competitive conditions. Beginning in the north with parts of Mercer County, dairying is found on the better soils where good hay, rotation pasture and corn for both silage and grain grow well.

Soybeans and some truck crops are grown on the lighter soils. Poultry, because it is relatively independent of soil productivity, often is located on farms where the fields are abandoned. But poultrymen are almost as prone to buy small tracts of good land near main roads and markets.

Mercer, Burlington and Camden Counties have their agriculture diversified and dispersed largely on the basis of soils. Dairying is less significant than further north and poultry is the dominant farm type in Camden County.

In Gloucester, Salem and Cumberland Counties, poultry was the most prevalent enterprise of farm families reporting in 1954. Vegetable farming is important because of the nearby metropolitan demand

for fresh produce and the related food processing industry. Dairying drops out of the picture on the lighter sandy soils where good hay and pasture crops are more difficult to maintain.

Across Delaware Bay, primary farm types in Kent County, Delaware, are dairy, field crop and poultry. Displaced potato farmers from Long Island have moved into the best dairy area near Dover, and are replacing some dairying with potatoes. Southern New Castle joins Kent and parts of Sussex in a partial rebirth of specialized vegetable production. Sweet corn acreage in New Castle, and asparagus and peas in New Castle and Kent Counties, have increased in recent years. Sussex grows a major portion of the cucurbits (watermelon, cantaloupe and cucumbers) in Delaware, and shares in production of most other vegetable enterprises. The shortage of farm labor for labor-intensive crops, good prices and increased yields, due to improved varieties and cultural practices, are encouraging the production of cash grain farming in corn and soybeans. Poultry production, generally, is in the south and west where it is associated with the larger Delmarva development.

Dairying crops out of the picture in Sussex County, as it does in southern New Jersey. Broiler production dominates the scene followed by cash grains. In Sussex, as elsewhere, current conditions make mechanized cash field crops more profitable and less troublesome than the labor-dependent vegetable crops grown previously.

Coastal Plain farmers have many alternatives. Relatively minor changes in the cost-return pattern among enterprises result in large shifts in farm organization. Technological change tends to outmode a situation before it can be stabilized. For example, construction of the Delaware Memorial Bridge has made it profitable for the world's largest producer-processor of vegetables to expand its farm activities into Delaware and to haul the shelled peas and lima beans to its New Jersey plant for processing.

5-03. SPECIALIZED FARMING IN THE CENTRAL NORTHEAST DAIRY AREA 1/

A study of dairy farms in northeastern Pennsylvania (Wayne County) provides the data used to illustrate modal tendancies for the Central Northeast Dairy area. The United States Census classifies approximately 75 percent of all farms in this area as specialized dairy farms.

Physical resources and climatic conditions here are only moderately favorable for general crop production. The soils are developed from glacial drift, mainly red and grey sandstones and shales. Their inherent fertility is about medium. Topography is mostly rolling to hilly, with some level areas along streams. On most farms the tilled cropland

1/ Meyers, K. H. and Pasto, J. K. Grassland in Organization of Dairy Farms in Northeastern Pennsylvania.

is limited to that which can be worked with power machinery. The lime requirement is high on all soils.

Poor internal drainage, resulting from the heavy, tight subsoil, probably is the most important factor limiting use of tillable farm land. However, some acreages of both good and poor soils are found on most farms.

Depending upon elevation and location, the frost-free season approximates 127 days. Annual rainfall approximates 40 inches. The relatively short growing season, abundant rainfall in spring and poor soil drainage conditions which delay early spring work combine to make grain crops uncertain. The climate is favorable to growth of grasses and legumes, but frequent summer rains make it difficult to produce and harvest high quality hay by field curing methods. The trend toward use of grass silage is a logical result.

Physical resources must be combined with large amounts of labor and capital to provide farmers with adequate incomes. Dairying, combined with a quality forage production program, is well-suited to these conditions.

Cropping systems are planned to provide the necessary roughages, including corn silage, hay and grass silage. Grains are of tertiary importance. Pastures have not received the same degree of attention that has been given to harvested forages. Production per acre on permanent pastures could be increased materially by proper management of these lands which have little alternative use.

No hay or pasture lands were irrigated on specialized dairy farms in the northern parts of this area of the Basin. One-third of the irrigation in the three New Jersey counties of Sussex, Warren and Hunterdon during 1954 and 1955 was for hay and pasture. Returns varied considerably.

Differences in cropland organization are due to a variety of reasons. Farms differ in soil productivity and in land use capabilities. Farm operators differ in ability, training, age, desires, or opportunities. Size of the dairy enterprise does not stand in a constant ratio to the acreages available for forage production.

a. Land Use and Cropping Practices. Farms averaged about 200 acres in size and included about 62 acres of cropland and 66 acres of permanent pasture (Table 8). Corn for silage, oats and grasses occupied 98 percent of the cropland on the farms studied. In 1950, hay was harvested on all farms and corn was ensiled on 66 percent of them. Grass silage was harvested on 28 percent of the farms, in most cases to supplement corn silage rather than to replace it. In addition to use for harvested roughage, some cropland, especially on large

TABLE 8. LAND USE DISTRIBUTION ON A "TYPICAL" FARM IN THE NORTHEAST DAIRY AREA, 1950 DELAWARE RIVER BASIN

Land Use		Dairy Farms Northeastern Pennsylvania 1/	Dairy Farms Central Northeast Dairy Area 2/
		Acres	Acres
Corn for silage		6.3	8.8
Oats		2.0	16.6 3/
Hay	1st cutting	43.4	(46.0
			(
	2nd cutting	(2.8)	(
Grass Silage	1st cutting	3.7	-
	2nd cutting	(0.5)	-
Cropland Pasture		6.0	-
Other Crops		0.6	0.6
Total Cropland Harvested		62.0	72.0
Open Permanent Pasture		66.0	72.0
Woods And Other Land		72.0	49.0
Total Farm Land		200.0	193.0

1/ These data were compiled largely from the text of Bul. 583. op.cit.
2/ ARS, USDA. Costs and Returns Commercial Family Operated Farms by Type and Size, 1930-1951. Stat. Bul. 197, pp.16-17, data for 1951.
3/ Small grains, largely oats.

farms, was used only for grazing.

An average of 6.5 acres per farm was seeded to oats on 72 percent of the farms, but less than half was harvested for grain. Oats serve as a nurse crop for new seedings of grass and legumes. The nurse crop frequently is harvested for hay or silage to provide additional forage and also to reduce competition with the new seedlings.

Few farmers actually follow a systematic rotation of crops. Corn silage and oats are grown most often on the better land, or in fields nearest the barn. On the poorer soils and the more distant fields, hay meadows are broken up only when it is thought necessary to re-seed the grass and legume stand. Acreages of corn silage and oats are reduced equally as the proportions of grassland are increased in the cropping system.

Most of the hayland on smaller farms in the study was harvested as hay. As the farm size and proportions of cropland in grass increased, a greater proportion was harvested as silage. However, total silage production per unit of dairy cattle was about the same on both small and large farms, grass silage replacing corn silage as the acreage of grassland increased.

Few farms had less than 60 percent of their cropland in grass. Average yields in 1950 were:

Silage Corn	8.4 tons
Oats	35.2 bushels
Hay - 1st cutting	1.7 tons
Grass Silage	5.5 tons
Cropland Pasture	1,313 lbs. TDN
Aftermath Grazing	450 lbs. TDN

With this yield distribution, corn silage produced more feed nutrients per acre than other crops. Grassland harvested for silage and then grazed was second. Oats ranked lowest. Thus, total production of feed would increase as grassland for hay, silage, or pasture replaced oats. On the other hand, production would decrease as corn silage was replaced with grasses.

It was estimated by the authors that average yields in this area could be raised, through use of adapted varieties and improved production practices, as follows: Corn for silage, 8 percent; oats, 29 percent; all hay, 59 percent; and production of feed from cropland pasture and aftermath, 75 percent. Improved practices would include good seeding methods, adequate lime and fertilizer, spraying for insect control and proper harvesting and storage. Irrigation of forage and pasture crops is not practiced in this type of farming area.

Assuming these attainable yields, it would be possible to increase feed production by 62 percent on all-grass farms. However, an increase in grassland over the 60 percent level would result in replacing corn silage with grass silage. There would be little change in total roughage produced above this level.

Success of operators in utilizing such changes in the cropping pattern will vary. To increase net returns, they must obtain the same output of milk at lower cost or a greater output of milk with little or no increase in cost per unit.

b. Livestock Production and Management. Sales of milk and dairy stock accounted for nearly 90 percent of cash income on these farms. A team of work stock often was kept for emergency use around the farm. A few pigs and chickens to provide meat and eggs for the home also were kept on most farms.

The average dairy herd had about 21 cows, 7 yearling heifers and 6 heifer calves. However, there was no consistent relationship between numbers of cows and the proportion of cropland in grass.

c. Feeding Practices. There was wide variation in feeding practices, depending on amounts and kinds of forage available and number of cows. Concentrates, including home-grown grains and purchased feed (but excluding grain in corn silage), made up about one-third of the total feed consumed by cows on the average farm. Less corn silage and more harvested grasses were fed as the proportions of grassland per farm were increased.

Forage producing ability is important in determining the size of the dairy enterprise. Production varied from 4.1 tons to 5.3 tons of hay equivalent per cow. Concentrates were fed at a much higher rate on farms having inadequate forage. As a result, there was no practical difference in total amounts of feed consumed (TDN) per cow, whether she were in a herd fed more or less than average proportions of roughage. Less forage, and also less total feed was consumed per cow, and milk production per cow also was somewhat less on small farms than on larger ones.

Use of high concentrate rations enables farmers to keep more cows and to get more milk per cow. However, in this area, where most of the concentrates are purchased, the value of the additional milk produced was barely sufficient to cover the increased feed bill. Labor earnings were greatest on farms where more home-grown forage and less purchased concentrates were fed.

Most dairymen recognized that their pastures had low milk producing capacity during the summer, but few tried to improve the forage-production of natural pastures. Instead, they increased concentrate feeding. Concentrates were fed at the rate of one pound to five pounds of four percent

milk during the spring and 1 to 3.1 pounds during the summer. Some hay and silage were fed in addition to concentrates on nearly all farms during the summer.

d. Farm Earnings. Gross farm income averaged about $9,100 for the year ending April 30, 1951. Purchased feed, labor, power and equipment made up 76 percent of total farm expenses. Investment in land and buildings accounted for about $11,500, or a half of the total farm capital investment (Table 9).

5-04. DAIRYING IN OTHER AREAS

a. Allegheny Plateau - Central Pennsylvania. Dairy herds in this mountainous sector tend to be smaller than in the Central Northeast Dairy area. Although a few herds of 50 or more cows can be found, the average and median herds contain about 12 cows and a half dozen young stock. The smaller herds usually are combined with other enterprises into a general farm type. Many families supplement farm earnings with income from tourist and recreational activities, or with nonfarm occupations. Nearly 40 percent of all farms in this area were classed as noncommercial and another 20 percent of the commercial farmers had farm incomes of less than $2,500 per year.

A statistically selected sample of farms in Monroe County, Pennsylvania, averaged 197 acres, of which 77 were in crops; 21 in pasture; 78 in woodland; and 21 in other uses. Although the apparent acreage in woodland and other uses is larger than for the Wayne County farm described earlier, much of the difference lies in definition of pasture and woodland pastured. Considerable variation exists between intensity of land use in the heavily wooded and the more open farming sections.

Climatic conditions always vary radically between locations in a hilly or mountainous area. Generally, the annual precipitation in these counties averages slightly higher than in the Wayne County example and the average, as snow tends to be heavier. Summer temperatures tend to run slightly warmer in the lower sectors and encourage production of corn for grain, potatoes, wheat and barley.

Hay still is the most widely grown crop. Corn for silage is utilized as a succulent roughage here, about as in Wayne County. Corn for grain, the small grains and potatoes loom more important in this area because: (1) Yields are relatively higher, and (2) the "general" or mixed types of farming interspersed with dairying require relatively less forage production per farm. Catch-crops (rye and buckwheat) and wheat, corn and potatoes as cash crops are grown fairly commonly on small dairy and general farms.

Average yields per acre probably could be raised economically by careful use of commercial fertilizers, lime and better cropping

TABLE 9. CAPITAL INVESTMENT, RECEIPTS AND EXPENSES ON DAIRY FARMS IN NORTHEASTERN PENNSYLVANIA DELAWARE RIVER BASIN *

Item	Dollars
Capital Investment	
Land	4,734
Buildings	6,793
Total Real Estate	11,527
Machinery And Equipment	4,056
Feed And Grain	153
Dairy Cattle	7,467
Other Livestock	308
Total	23,511
Receipts	
Crops: Sales Plus Inventory Changes	199
Livestock: Net Increase From Sales, Purchase, And Inventory Changes	1,892
Dairy Products: Sales	6,288
Other L. S. Products: Sales	451
Miscellaneous: Sales	278
Total	9,108
Expenses	
Crop Production: Fertilizer, Lime, Seed, Twine, etc.	372
Livestock Production: Veterinary, Breeding Fees, etc.	125
Feed Purchased	2,797
Labor (hired and unpaid family labor)	1,003
Machinery and Equipment: Depreciation, Repairs, Fuel, and Oil	1,032
Buildings: Taxes And Insurance, Other	1,008
Total	6,337
Net Farm Income	2,771
Interest On Investment - 5 Percent	1,176
Labor Income 1/	1,595

1/ In addition, the operator and his family received use of the house and obtained other perquisities, such as meat, eggs, milk, and garden products.
* Thirty-six farms, weighted to represent all dairy farms with 10 or more cows. From Table 10, Bul. 583. op. cit.

practices. However, many farm operators are elderly and are satisfied with essentially a subsistence type of farming. Irrigation of forage crops is not practiced in this area.

b. Northern Piedmont Dairy and General Farming. Dairying was the major occupation among commercial farmers in this eight-county area during 1954, but it was followed closely by poultry, field crop and general farms in some counties.

Physical resources and climatic conditions generally are favorable to production of both forage and grain. Winters are relatively mild and the summers are not excessively hot, although high humidity tends to increase the discomfort of both men and animals. An average frost-free period of about 170 days is ample for crops commonly grown. Average precipitation of 40 to 45 inches is distributed fairly uniformly throughout the year. Pastures tend to become short during the hot summer months and supplemental feeding of dairy cows becomes necessary to maintain milk production. Some farmers who have water sufficient for supplemental irrigation use irrigated rotation pastures while others plant special warm-weather pasture crops, harvest early-grown grasses as silage for summer use, or feed hay during this period.

Topography of this region is rolling to hilly and tends to limit the acreages of row-crops which can be grown. It is a transitional area between the mountainous section where grasses in long rotations must be utilized to conserve the soil and the sandy coastal section where grasses and pastures are difficult to maintain.

Cropping practices here differ considerably from those of the two previous areas. Farms are somewhat larger and the ratio of cropland to total land is larger. Cropland used for rotation pasture bulks larger on these farms than in the hill areas. Corn for grain, barley and oats generally yield well, although hot dry weather during the grain-forming period may reduce yields.

Some dairymen utilize most of their grain in home-grown rations, but probably more will sell grain or feed it to other livestock and buy ready-mixed rations for their milking herds. A recent study by the University of Delaware reports that a typical feed mix for dairy cows is:

300 pounds	36 percent concentrate
600 pounds	barley
600 pounds	corn and cob meal
300 pounds	oats
150 pounds	molasses
50 pounds	salt
2,000 pounds of mix 1/	

1/ McDaniel, Wm. E and West, Wm. H. Profitability of Alternative Forage Programs on Delaware Dairy Farms. University of Delaware Department of Agricultural Economics AE Pamphlet 14, December 1956, page 4.

This report also states that cows are fed at a ratio of one pound of grain to three pounds of milk produced in winter and in summer the ratio is broadened to 1:4.7. Milk production averaged 6,668 pounds per cow in the northern New Castle County portion of the Delaware study. Production at this level is roughly comparable with averages for specialized dairying states. Some effort is made to even out seasonal production variations to take advantage of seasonal price advantages in the Wilmington-Philadelphia market.

Truck crop production as a supplemental enterprise has largely disappeared from these farms due to the economic squeeze and pressures for intensive milk production. Occasionally, further north in Pennsylvania, a few dairymen will grow early peas, late cabbage, or similar special crops which fit well into their labor distribution program. A few families still grow vegetables for sale at curb markets, roadside stands and other small specialized outlets.

5-05. POULTRY FARM ORGANIZATION

It is practically impossible to describe a "typical" poultry farm. Some poultrymen specialize in egg production, some produce broilers only and a few produce both eggs and meat birds. Some grow crops unrelated to poultry production, some have cropland they don't use and still others have only sufficient lands for their poultry houses and residence. In some cases the actual grower will be operating under financial arrangement whereby he invests his time and limited other resources for a share of the proceeds from an enterprise financed by a landlord or a feed company.

The purpose of the present report is to provide background information about present agricultural enterprises which might require water, particularly water for irrigation. Since poultrymen as a group and the poultry enterprise, per se, require water for domestic and livestock use only, little purpose would be served by discussing poultry management in the present context.

5-06. TYPICAL TRUCK CROP FARMS

Some truck crops for sale are produced in practically every county of the Delaware Basin. However, intensive production is concentrated on the sands and sandy loams of the Coastal Plain. Production of specific crops is further concentrated within rather narrow limits of soil conditions although this situation is modified by the location of processing plants freezing or canning the crops involved.

Commercial orchards seem to be fading out in the Basin as a whole. However, significant remnants of apple and peach orchards are included in farm operations of many truck farmers of New Jersey and Delaware, and some new orchards are being set out. In fact, the acreage of peach trees

in Gloucester County, New Jersey, increased between the Censuses of 1950 and 1954. Some of the increased acreage in new orchards appears to have been set out in anticipation of urban-residential developments rather than as an economic agricultural enterprise.

The New Jersey cranberry enterprise, which has been concentrated largely in Burlington County, has declined rapidly in recent years. Further acreage reductions are almost certain to occur. Some of this acreage has been lost through urban and industrial encroachment but a larger portion of it probably has been abandoned due to low production and now lies idle. Cranberry acreage probably will continue to decline as these lands are converted to other uses, such as, lake developments, water supplies and camping areas.

The acreage of tame blueberries in this section has increased about as rapidly as the acreage in cranberries has decreased. Further increases are anticipated. Most of the new acreage will be on virgin farmland developed from swamps and woodland.

As with poultry, it is difficult to isolate and describe a typical truck crop farm. Before the days of frozen foods, mechanized farming, short labor supply and supplemental irrigation, a large number of small farms produced a significant acreage of truck crops for fresh market and canning purposes. Some of these still remain, but largescale operations have become dominant in recent years. Some of these large operations specialize in producing one or two crops; others will grow relatively small acreages of 15 to 20 vegetables. In such cases, two or three crops will be grown successively on the same fields each year. In some cases, dairymen will grow acreages of vegetables which fit well into their farm plans and grow well on their farms.

Indicative of the group which grows large acreages of a few crops is a sample from Burlington County, New Jersey. 1/ All of these farmers specialize in growing sweet corn, their acreages ranging from 10 to 100 in this single crop. Apple and peach orchards formerly were significant in this area, and two-thirds of the farms still average 24 acres in peaches. Others in this group grow tomatoes, melons, squash, green beans, potatoes, grapes, strawberries, or other specialty crops. Relatively few grow grain crops and none reported hay production since practically no livestock are kept. The average size of farm was about 120 acres with 97 acres in crops and the remaining 24 acres in woods, pasture, marsh, waste, farmsteads and other uses.

Further south, in Gloucester, Salem and Cumberland Counties, is a section of concentrated asparagus production. Farm size in the sample

1/ Unpublished data from a study of irrigation farming being conducted by the Department of Agricultural Economics at Rutgers University.

averaged 131 acres of which 94 were cropland and 37 were in woods or non-crop uses. These farms averaged 14 acres of asparagus, 20 acres of tomatoes and 59 acres of other vegetables of which some usually were double or triple cropped. A great variety of vegetables was grown, including broccoli, cabbage, cucumber, chinese cabbage, cantaloupe, egg plant, horseradish, lima beans, green beans, lettuce, pumpkins, squash, peas, peppers, onions, white potatoes and sweet potatoes. Other farmers not included in the sample, undoubtedly, would have added to this list. Some field corn, soybeans, wheat and other grains were grown for sale on about half of these farms. No significant numbers of livestock were kept.

In one localized area having heavier soils, dairying, truck crops and field crops do well together. These combination farms are larger than those specialized truck farms just described. They average 218 acres of which 168 were in crops, 35 in permanent pasture and 15 in miscellaneous uses. Some had relatively large acreages of asparagus or tomatoes. Some produced both of these crops together with an average of 30 acres in miscellaneous vegetables. Orchards and small fruits do not occur usually on these farms. Other crops include an average of 51 acres of field corn, 22 acres of soybeans and 20 acres of hay. About one-third of all farmers in this survey rented some part of their cropland for vegetable production.

A study of organization and production practices on vegetable farms in the western half of Sussex County, Delaware, which is outside the Basin but otherwise comparable to adjoining Basin-contained areas, indicated that farm size there ranged from 27 to 382 acres in 1951. 1/ The average was 141 acres per farm. Sixty-eight percent of the land was tillable and slightly over one-fourth was woodland.

Corn was the only crop grown on all farms. Soybeans ranked second, followed by tomatoes. Only 19.5 percent of the tillable land was in vegetables and fruits, but nearly a third of total cash receipts was from these crops. The acreage distribution per farm is shown in Table 10.

Use of water for irrigating high value truck crops and orchards has been increasing rapidly in the Coastal Plain area. The practice, undoubtedly, will increase if water is available and if the net returns to irrigation are favorable. Studies now in progress, or to be started in the near future, will provide limited guides for economic analysis of this practice.

1/ McDaniel, William E. Influence of Organization and Production Practices on Income of Delaware Vegetable Farms. University of Delaware Agricultural Experiment Station, Bul. 296, June 1953.

TABLE 10. AVERAGE CROP ACRES AND YIELDS, 92 FARMS, 1951 1/
SUSSEX COUNTY, DELAWARE
DELAWARE RIVER BASIN

Item	Farms Growing Crop	Acres Per Farm For Farms Growing Crop	Acres Per Farm For 93 Farms
	Number	Average	Average
Barley	17	10.3	1.9
Corn	93	31.1	31.1
Oats	11	7.6	.9
Rye	56	11.8	7.1
Soybeans	79	28.9	24.5
Wheat	38	16.1	6.6
Total Grain Crops			72.1
Lespedeza Hay	52	8.4	4.7
Other Hay	36	6.1	2.4
Asparagus	17	3.8	.7
Beans, Lima	24	28.0	7.2
Beans, Snap	3	23.3	.8
Cantaloupes	27	4.7	1.4
Cucumbers And Pickles	27	2.5	.7
Corn, Sweet	7	6.3	.5
Peppers	32	3.1	1.1
Pumpkins Or Squash	3	1.6	.1
Sweet Potatoes	6	9.8	.6
Tomatoes	73	4.1	3.1
Watermelons	19	4.6	.9
Other Vegetable Crops	5	4.8	.3
Total Vegetable Crops			17.4
Apples	3	9.0	.3
Peaches	4	18.8	.7
Strawberries	12	2.7	.3

1/ From Table 2, Bul. 296. op.cit.

APPENDIX TABLE 1. CROP YIELDS, 1939-54
DELAWARE COUNTY, NEW YORK

Crop	Unit	Year 1939	1944	1949	1954
Corn for silage	Ton	-	-	10.04	11.3
Corn for grain	Bushel	36.0	39.8	41.3	52.8
Wheat threshed	Bushel	27.1	25.8	32.2	29.7
Oats threshed	Bushel	32.6	34.3	33.9	37.5
Barley threshed	Bushel	18.4	19.2	14.6	26.9
Soybeans for beans	Bushel	23.3	15.6	20.0	-
Hay Cut, excluding soybeans	Ton	1.2	1.5	1.4	1.7
Grass Silage	Ton	-	-	5.8	6.3
Irish Potatoes	Bushel	89.7	71.8	98.4	135.4

APPENDIX TABLE 2. CROP YIELDS, 1939-54
LEHIGH COUNTY, PENNSYLVANIA

Crop	Unit	Year 1939	1944	1949	1954
Corn for silage	Ton	-	-	7.9	7.7
Corn for grain	Bushel	30.8	33.2	49.5	47.6
Wheat threshed	Bushel	18.0	-	22.6	27.9
Oats threshed	Bushel	23.8	29.2	30.6	37.7
Barley threshed	Bushel	30.6	28.1	40.1	42.4
Soybeans for beans	Bushel	10.2	16.4	19.0	18.9
Hay Cut, excluding soybeans	Ton	1.0	1.3	1.7	1.6
Grass Silage	Ton	-	-	3.6	6.7
Irish Potatoes	Bushel	117.5	136.8	257.8	268.1

APPENDIX TABLE 3. CROP YIELDS, 1939-54
BURLINGTON COUNTY, NEW JERSEY

Crop	Unit	Year 1939	1944	1949	1954
Corn for silage	Ton	-	-	9.8	9.0
Corn for grain	Bushel	36.4	37.5	45.2	50.7
Wheat threshed	Bushel	20.2	21.1	21.8	29.3
Oats threshed	Bushel	21.4	23.6	35.3	39.2
Barley threshed	Bushel	28.3	27.1	37.8	41.8
Soybeans for beans	Bushel	18.6	13.2	18.8	19.1
Hay Cut, excluding soybeans	Ton	1.6	1.7	1.9	2.4
Grass Silage	Ton	-	-	5.1	5.6
Irish Potatoes	Bushel	129.1	143.2	183.2	243.6

APPENDIX TABLE 4. CROP YIELDS, 1939-54
NEW CASTLE COUNTY, DELAWARE

Crop	Unit	Year 1939	1944	1949	1954
Corn for silage	Ton	-	-	8.4	8.0
Corn for grain	Bushel	28.8	34.6	47.4	42.0
Wheat threshed	Bushel	20.2	21.2	19.1	27.8
Oats threshed	Bushel	27.7	34.8	36.7	40.5
Barley threshed	Bushel	31.3	31.4	37.3	38.8
Soybeans for beans	Bushel	13.0	12.8	16.6	17.6
Hay Cut, excluding soybeans	Ton	1.2	1.3	1.5	1.4
Grass Silage	Ton	-	-	5.1	5.3
Irish Potatoes	Bushel	73.8	64.8	115.1	181.3

APPENDIX TABLE 5. TWENTY-SEVEN COUNTIES WHOSE AGRICULTURAL STATISTICS AND FARMING DATA WERE UTILIZED IN THIS REPORT
DELAWARE RIVER BASIN

New York

Delaware
Sullivan

Pennsylvania

Berks	Monroe
Bucks	Montgomery
Chester	Pike
Carbon	Schuylkill
Delaware	Wayne
Lehigh	Philadelphia
Northampton	

New Jersey

Burlington	Salem
Camden	Sussex
Cumberland	Warren
Gloucester	Hunterdon
Mercer	

Delaware

New Castle
Kent
Sussex

PART C - FORESTRY

SECTION I - INTRODUCTION

1-01. PAST USE OF THE FOREST

Man has used and abused the forests of the Delaware River Basin for some 300 years. When the white settlers first arrived, the Basin was densely forested with fine stands of timber. To these early settlers the forests were often the hindrance to development and much of the forest land was cleared for homes and farms without regard to future forest productivity.

During the last of the 18th and the early part of the 19th centuries, the lower Basin was dotted with blast furnaces producing iron from the ore deposits that had been discovered throughout the area. Thousands of acres were cleared of trees to make charcoal for the furnaces. Other thousands of acres were stripped to provide fuel wood for what was even then becoming a great metropolitan center. Discovery and development of the anthracite coal reserves during the 19th century made further exorbitant demands on the dwindling timber resource. By the time of World War I these mines had an annual wood requirement of over 50,000,000 cubic feet and on the lands nearest to the mines, where delivery costs were lowest, every tree was cut that would make a "prop." By 1915 most of the Basin had been cut over at least once for lumber and other forest products. Many of the forests were clear-cut and the immature forests which replaced them have been repeatedly cut whenever they were within easy reach of market for small size timber. Where the forests were not completely cleared, most of the cutting has been a "high-grading" proposition, taking the best and leaving the undesirable. This has gradually created a preponderance of the less desirable species and a large percentage of cull trees in most of the remaining stands.

Devastating fires frequently followed in the wake of the cutters and until comparatively recent times no concerted attempt was made at fire control. In an area as heavily used as this forest has been, it was inevitable that great fires should sweep the area time after time. In a few localities, especially in the anthracite region of Pennsylvania, and in the sections of New Jersey, these fires have been so frequent and so severe that desirable species have been largely killed out and only the highly fire-resistant scrub oaks remain.

In the coal mining regions, in addition to clearing the land of trees or mine wood, extensive areas were mined by "stripping" operations which left many thousands of acres of spoil banks completely unfit for new tree growth and which remained as continuing sources of sediment and excessive surface run-off.

Many of the acres cleared for farm land were on slopes and soils unsuitable for farming and have since been abandoned. Although some of this land has reverted naturally to brush and tree cover, much of it still remains bare and eroded and a source of unregulated run-off.

As the great expanses of clear-cut and burned forest land gradually became covered with stands of brush, an ideal breeding ground for deer was created. As a result of well-meaning but poorly informed sentiment for protection, the deer herd grew to unmanageable proportions. This overstocking resulted in almost complete destruction of tree reproduction over large areas. The "browse line", as high as a deer can reach and below which tree limbs and underbrush are gone, is still evident. In Pike and Monroe Counties, Pennsylvania, deer browsing became so heavy that the Department of Forests and Waters was forced to abandon, temporarily, all attempts at forest planting on state lands.

1-02. PRESENT FOREST

Despite all of man's encroachments and misuse, lands classed as "forest" still occupy approximately one-half of the Basin area. A large portion of the forest is in young age classes and, as a whole, the stands are understocked and contain many inferior and undesirable species. Due to the wide range in climate, topography and soils found throughout the Basin, the forest types also vary greatly. They range from spruce and northern hardwoods in the northern end of the Basin to southern pines on the Coastal Plain. However, various oak types and mixtures are most prevalent and occupy about 40 percent of the forested area, principally in the central Basin.

For the most part, these forests are on good-to-excellent growing sites and under proper management could make a much greater contribution to the economy of the Basin then they are now doing. Even at their present rate of growth, more wood is being grown than is being cut. This is due, principally, to the fact that most of the growth is on young trees too small for marketing and on inferior and undesirable species.

For the most part, the forests occupy steep, thin-soiled lands strategically situated in the headwaters of the Basin's tributary streams. They are ideally located to have a significant effect on the regulation of waterflows and the prevention of floods in the streams. However, because of their present condition, the forests are exerting an influence far below their potential. Recent surveys show that only 10 percent of these forest lands are in good hydrologic condition, another 40 percent are rated as fair, and the remaining 50 percent as poor.

1-03. USE OF FORESTS

The greatest direct use of these forest lands is by people seeking outdoor recreation. The steep topography and relatively high elevations

of much of the forest area makes it aesthetically attractive and provides an appealingly cool climate and relief from the hot, humid summers of the coastal areas. The Catskill Mountains in New York, and the Poconos and adjoining mountains along the Delaware River in eastern Pennsylvania and northwestern New Jersey, constitute the nearest mountain recreation for millions of people.

No estimates exist that would give an idea of the size of the dollar income to the Basin from recreation and hunting and fishing use of the forests. It must, however, be a very impressive figure. In three counties of the Basin (Sullivan County, New York, and Monroe and Pike Counties, Pennsylvania) the employment at hotels and lodging places is 12, 9, and 8 percent, respectively, of the total employment of the county. These figures compared with a regional average of about 1 percent for this type of employment, gives some idea of the importance of this business. The Poconos boast 80 percent of all resort facilities in the entire State of Pennsylvania. Ninety thousand acres are owned by commercial resorts and hunting clubs in Monroe County alone. Nearly 10 percent of the forest land in the Basin is being managed primarily for wildlife benefits. As great as these uses now are, they will inevitably grow tremendously as increases in population and leisure create greater demands. The value of the forests for recreational use, both now and in the future, is probably second only to their importance in regulating water flows. These uses are not mutually exclusive and under proper management major benefits could be realized from both.

Even in their present depleted condition, the forests of the Basin are making a significant contribution to its economy through the harvest and sale of forest products. In 1955, an estimated 60,000,000 board feet of sawtimber and 45,000 cords of other wood products were cut. This netted a cash return to the landowners of approximately three-quarters of a million dollars for stumpage. If to this sum is added another $2,000,000 paid to woods workers for cutting and removal of timber from the forest and $5,000,000 from primary processing, it will be seen that the woods industry in the Basin amounted to approximately $8,000,000, primarily for wages and stumpage. The sale of equipment and supplies to maintain this operation brings the total to a round figure of about $10,000,000. This is an appreciable figure but, under good forest management yields, could be increased so that it would be multiplied five-fold.

The sale of forest products from farms in the Basin in 1954 was approximately $1,000,000, a fraction of 1 percent of the total value of farm products sold. At this rate, cash income to farmers from their woodlots would average about $1.00 per acre per year. Fuel wood, fence posts and similar material used on the farm is not included in this figure and would probably double the annual return. However, considering the fact that about one-third of the average farm is in woodland, this

is a very small return on relatively high value land. To quote Commissioner McLean, of the New Jersey Department of Conservation and Economic Development -

> "It is absolutely certain that under management the production from farm woodlots in the Delaware Basin could be materially increased.....The resources that are being wasted by inadequate management of the small woodlots would reach a substantial figure. The farm woodlots are generally located in the better farming areas and, therefore, would have a relatively good quality of hardwoods which would predominate. Good stands of soft woods would be found on farm woodlots in the better farming areas of the Coastal Plain. Because of the location, timber in the Delaware Valley brings excellent prices."

1-04. TRENDS IN FOREST MANAGEMENT

As a result of organized cooperative efforts by the states and the federal government, protection of the forests from destructive fires and insect and disease epidemics is virtually assured. In response to public sentiment and as an awareness of the potential values of productive forest land increases, destructive logging is showing a slow but steady decline. As awareness develops of the public values inherent in well-managed forest land for the regulation of waterflow, for recreational use and for other contributions to the economy of the area, it seems inevitable that the public will adopt whatever means are necessary to assure good forest land management. Although the total acreage of forest land in the Basin will, undoubtedly, decrease as shifts in land use take place, the gains that will result from improved conditions on the remaining acreage should be such as to make a major contribution to the water resource situation in the Basin.

USE AND MANAGEMENT OF LAND AND COVER RESOURCES OF THE DELAWARE RIVER BASIN

CHAPTER II

SOILS

SECTION I - INTRODUCTION

Soil formation is influenced by such factors as parent material, climate, organisms, topography and time. The kind of soil formed at any one location reflects their combined effects. The different kinds of soils formed at different spots reflect the dominance of one or more of these factors.

Soils begin their history with the accumulation or exposure of finely divided, weathered rock materials. The next step, often coincidential with the first, is the introduction of living organisms and the beginning of the constructive phases of the soil-forming process. As the soil-forming process operates upon the rock materials, changes are slowly brought about in the surface layers which, if allowed to continue for a long time, will make those layers very different from the parent material. The changed portion, which is regarded as the true soil, may vary in thickness from a mere film to several feet. The character and thickness of the soil thus formed depends on the intensity of the soil-forming processes, the time during which they have acted, and the resistance of the parent material to change. When a soil has developed certain definite characteristics, irrespective of the time lapse, it is said to be a mature or a well developed soil.

The soils in the Delaware River Basin vary from youthful soils in the bottom lands to mature soils in the uplands. The northern half of the Basin was covered by glaciers. The soils within this area are generally less mature than the undisturbed soils in the southern part of the Basin.

Soil development is affected by mechanical agencies. The surface layer may be wholly or partly removed by erosion, exposing the material beneath. The soil-forming processes then begin anew on the material thus brought under their influence. Whether this change is detrimental or beneficial to the growth of plants depends on the rate of removal and on the supply of nutrient elements in the newly formed surface layer.

Since the forces that are building up, changing, or destroying the soil are not uniform over the Delaware River Basin, the soils of the Basin show a corresponding lack of uniformity. Even within a comparatively small region, local soil series vary enormously in their inherent productivity for the prevailing type of farming generally adapted to the region as a whole. Only rarely are there large areas of soil uniformly productive and unbroken by patches of stony, hilly, or otherwise unsuitable land.

The soils in the Delaware River Basin have been formed from parent material that varied from hard crystalline rocks to lake-plain sands and clays and Coastal Plain deposits of sands, silts and clays. The soils developed from glaciated materials are of two general kinds: first, those developed from the ground up mantle of rocks and debris, or glacial till, under the glaciers themselves; and second, the relatively coarse glacial outwash materials carried by the large, swift-flowing streams generated as the glaciers melted. In the Upper Delaware Basin, both the glacial till and the glacial outwash soils are largely formed from sandstone and shale rock materials.

SECTION II - SOILS DESCRIPTION

2-01. PHYSIOGRAPHIC REGIONS OF THE DELAWARE RIVER BASIN

Topographically, the Delaware River Basin has been grouped into three major divisions: the Mountainous and Upland Plateau is designated as Physiographic Region 1; the Ridge and Valley and Piedmont Plateau Area, including the Triassic Basin and the Southern New England Upland and Northern Shale and Limestone Belt, is designated as Physiographic Region 2; and the Coastal Plain Area is designated as Physiographic Region 3 (Fig. 10). Regions 1 and 2 are part of the Appalachian Highlands and Region 3 corresponds to the Coastal Plain as defined by Fenneman in "Physiography of the Eastern United States." Table 11 shows the basic natural physical conditions of the soils in the Delaware River Basin.

Physiographic Region 1

This Region, consisting of about 3,000,000 acres, comprises the northern third of the Delaware River Basin. It is made up largely of sections of the Catskill and Pocono Mountains in the north and sections of the Appalachian Valleys and Ridges in the south. (These areas are designated as B8d, B8c and B14b in Fig. 10.)

The Region rises to elevations of about 3,000 feet. In general, it consists of a deeply dissected plateau with valleys having steep and precipitous slopes. Glaciation has rounded and softened the topography, but there are many long, steep slopes leading from the upland plateau to deeply-cut narrow waterways and to the valley floors. These long, relatively narrow valley floors vary in width from 100 yards to more than a mile. In places, moderately sloping till lies on the sides of the valleys. The plateau tops are mostly gently to moderately sloping. Bedrock outcrops are common.

Pocono-Catskill Section -

The soils in the Pocono Catskill section (designated as B8d and B8c in Fig. 10) are derived from glacial till and outwash material, coming largely from the local non-calcareous sandstone and shales but with some

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TABLE 11. NATURAL PHYSICAL CONDITIONS
(TOPOGRAPHY, CLIMATE, SOILS)
DELAWARE RIVER BASIN

Physiographic Regions	Physiographic Region In Basin	Problem Areas In Soil Conservation	Counties And States Represented	Topography	Elevation	Climate: Average Rainfall	Climate: Average Frost-free	Bedrock Or Soil Parent Material	Typical Soils	Glacial Influence
	Percent				Range in Feet	Inches	Days			
I. Mountains or Hilly Uplands	42			Rugged to hilly and rolling	500 - 3,000	40-45	110-150			
a. Catskill and Pocono Mts. and Foothills		B8c, B8d	Delaware, Sullivan, N. Y.; Wayne, Pike, Pa.; North Sussex, North Warren, N. J.					Sandstone, shale, glacial till	Wellsboro, Oquaga, Culvers, Lordstown	Yes
b. Ridges and Valleys		B14b	Monroe, Carbon, Schuylkill, Pa.					Sandstone, shale, slate, quartzite, limestone, glacial till	Hazleton, Weatherly, DeKalb, Drifton and Weikert	Yes
II. Intermediate Uplands (mostly Piedmont Plateau (some Ridge and Valley)	35			Hilly and rolling to gently sloping	200 - 1,000	40-45	160-170			
a. Piedmont Plateau 1. Glaciated		B9, B2e, B10a	Central and South Sussex, Central and South Warren, North Hunterdon, N. J.; South Lehigh, South Berks, North Bucks, Pa.					Shales, slates, sandstone, limestone, glacial till	Norton, Washington, Kestler, and Weikert	Yes
2. Non-glaciated		B10b, B11	South Hunterdon, North Mercer, N. J.; Chester, Delaware Montgomery, South and Central Bucks, S. Berks, Pa.; N. New Castle, Del.; Cecil, Md.					Shale, slate, sandstone, limestone, granite, gneiss, schist	Penn, Chester, Berks and Manor	No
b. Limestone Valleys		B14c	North and Central Northampton, North and Central Lehigh, North Berks, Pa.					Limestone, shale slate, sandstone, glacial till	Duffield, Hagerstown	No
III. Coastal Plain	23	A1b, A1c, A2b	South Mercer, Burlington, Camden, Gloucester, Salem, Cumberland, N. J.; Central and South New Castle, Kent, Sussex, Del.	Gently sloping to flat	0 - 300	40-45	180-190	Marine laid deposits, sands, silts, clays	Sassafras, Woodstown, Elkton, Keyport	No

admixture of crystalline rock. Nearly all of the soils are gravelly or flaggy, and the steep slopes of the shallow soils are frequently stony. Occasionally, the outwash soils, such as Tunkhannock, occur in relatively extensive terraces; but much more frequently, the rolling, knobby, kame deposits predominate. Extensive areas of smooth, undissected bottom land soils, such as Barbour and Basher, are rare.

Generally, the soils are acid and low in natural fertility and vary in moisture-holding capacity. Moisture storage in the soil is often limited by hardpan at depths of 12 to 18 inches and shallowness to bedrock. Two of the shallow, somewhat droughty soils are Catskill and Oquaga, which cover extensive areas. In contrast, Lackawanna, which is deep and well-drained, and Culvers and Wellsboro, which are deep and moderately well-drained, have a higher moisture-holding capacity.

Appalachian Valley and Ridge Section -

In the Appalachian Valley and Ridge section (designated as B14b in Fig. 10), the soils are derived from a wide variety of parent rock materials, including acid gray sandstone and conglomerate, both acid and calcareous gray and red shales, pure limestone and quartzite. Although there are soils with hardpans and some poorly drained or premanently wet lands in this area, well-drained soils predominate. The combination of these factors gives rise to a wide variety of soils.

With such a wide range of soil depths and kinds of parent material, there is a great variation in available moisture capacity and groundwater relations. Much of the shale land suffers from lack of sufficient available moisture capacity.

Some of the principal soils are Hazleton, which is deep and well-drained; Dekalb and Weikert, which are shallow and well-drained; and Drifton, which is deep and moderately well-drained.

Because of the shallow soils and limited storage capacity, the streams draining the entire Physiographic Region are characteristically flashy and are well typified by the Brodhead Creek and the Lehigh and Lackawaxen Rivers, where storms of moderate intensity may cause sharp increases in stream discharge.

Because of unfavorable soil conditions and rugged topography, only a fifth of the Region is in farmland, and about one-seventh of the land area is in cultivation. Much of the land has remained in forest (Table 13). The forest cover is largely hardwoods. The area experiences the cool summers and cold winters associated with elevations up to 3,900 feet.

Physiographic Region 2

Physiographic Region 2 is a very important part of the Basin from

an agricultural standpoint. The area is about 2,700,000 acres in extent (designated as B9, B2c, B10a, B10b, B11 and B14c in Fig. 10).

Agricultural production in Physiographic Region 2 is diversified. The abundance of deep, well-drained soils, together with favorable climatic conditions, lend themselves to the production of a variety of farm crops. They range from market gardening crops in the areas near the large cities to canning crops, dairying and general farming. Much of this area has been farmed longer than any other part of the Basin. However, at present, the expansion of suburban residences and industries is removing large areas from the farmland acreage.

Ridge and Valley Section -

The Ridge and Valley area (designated as B14c in Fig. 10) forms a belt running across the Delaware River Basin from northern New Jersey through eastern Pennsylvania. It is an area of low mountains between the Appalachian Valleys and Ridges and the Piedmont Plateau. The ridges rise from 200 to 1,000 feet above the general level of the valleys. Area-wise, it is about 600,000 acres in size.

Two principal sub-divisions are the predominantly limestone areas along the south side of the area and the shale and slate belts to the north. In both parts, the soils are nearly all well-drained. The soils of the limestone area are highly productive and well adapted to a wide variety of crops.

The main body of limestone in this area extends from Berks County to the Delaware River. The soil parent material is limestone and cement rock. Some of the principal, deep, well-drained soils are Washington from glaciated material; Ryder, which was formed from cement rock; and Duffield, which was formed from unglaciated limestone material. Slopes are mostly gentle to moderately steep. They are mostly smooth and uniform except in an area just west of Allentown, where a glacial moraine has formed a very rough surface.

In the shale and slate sections, the principal soils are Kistler, which is moderately deep and well-drained; Weikert, which is shallow and well-drained; and Berks, which is deep and somewhat droughty. Slopes range from gentle to steep, with a high proportion of the area being moderately steep.

In the limestone and slate sections, soils generally are sufficiently deep to have high available moisture capacity. In dry seasons, all of the soils, particularly the shale soils, will respond very favorably to additional water.

The Piedmont Plateau Section -

The Piedmont Plateau section (designated as B10a and B10b in

Fig. 10) is split by the Triassic Basin into two areas. The northern area (designated as B10a in Fig. 10) forms a belt across the Basin from central New Jersey into eastern Pennsylvania. It is less than 500,000 acres in size.

The southern part (designated as B10b in Fig. 10) of the Piedmont Plateau lies in a broad belt across the extreme southeastern part of Pennsylvania and northern Delaware into south central New Jersey. Area-wise, it is about 800,000 acres.

The soils of the Piedmont Plateau are mostly derived from gneisses, schists and quartzites. They have been formed by weathering in place of these local rocks. Gradual movement during a long period has built deep soils on the lower slopes; on steeper slopes, the soils are generally moderately deep. Slopes are generally moderate, but range up to very steep. Nearly all the soils are well-drained, except along streams and on lower slopes where there is wet season seep. The principal soils are Chester, deep and well-drained; Glenelg, moderately deep and well-drained; Manor, shallow and well-drained; and Glenville, deep and moderately well-drained.

Triassic Basin -

The Triassic Basin is an area of sandstone and shale extending through the Piedmont in Pennsylvania and into New Jersey (designated as B11 in Fig. 10). It has a smooth or gently undulating to rolling relief. The total area is slightly over 600,000 acres. A very high proportion of the entire area is in farms.

Geologic conditions, such as faulting, folding and intrusions, make it hard to generalize for the whole area which sub-divides naturally into shale areas, sandstone areas, ironstone ridges, and a number of other areas which do not fit well in any of these three groups.

The shale areas are predominantly areas of low hills at elevations ranging from 100 to 800 feet. The sandstone areas have more rugged hills. The ironstone ridges are distinctly higher than their immediate surroundings and range up to about 1,400 feet at the highest elevation.

The largest part of the Triassic shale lands lies in Berks, Chester, Hunterdon, Montgomery, Mercer and Bucks Counties. It is an area of rolling uplands at elevations from 100 to 600 feet. Soils range from deep to very shallow, with moderately deep soils most extensive. Drainage ranges from good to very poor, with moderately poor and poor most extensive. The soils are mostly residual from red shale formation. In extensive areas of Montgomery, Bucks, Mercer and Hunterdon Counties, the red shale is covered by a blanket of brown silt which makes the soil deeper and more uniform than is usual for a shale area. A compact silty pan makes drainage very slow on some of the soils.

The Penn soils are the most extensive soil series in the Triassic Basin. Most of these soils are moderately deep. The Penn shale loam is shallow and, therefore, presents difficult management problems. Serious management problems are also present in soils with impeded internal drainage, such as Readington.

In parts of this Triassic Basin, the shallow soil over shale becomes waterlogged during wet seasons but is very droughty at other times because of low total water storage capacity. Much of the rainfall is lost through rapid run-off.

Southern New England Upland and
Northern Shale and Limestone Belt -

The two remaining areas that complete the make-up of Physiographic Region 2 are the Southern New England Upland (designated as B2e in Fig. 10) and the Northern Shale and Limestone Belt (designated as B9 in Fig. 10).

The small area of Southern New England Upland and Northern Shale and Limestone Belt that lies within the Basin in northern New Jersey and eastern Pennsylvania is an area of undulating to rolling topography with moderately steep slopes. The entire section has been glaciated, and the soil materials consist of glacial till derived largely from the underlying rock which is calcareous and non-calcareous shale, slate and limestone. The area is about 260,000 acres in size.

Physiographic Region 3

The Coastal Plain area in the Delaware River Basin contains about 1,700,000 acres (designated as Alb and Alc in Fig. 10).

The Coastal Plain slopes gently seaward, usually in a series of terraces. These terraces extend inland along the bays and streams of the area. The fringes around the coast bordering the inner and outer Coastal Plain portions are tidal marshes, totaling about 30,000 acres in extent. These tidal areas consist of mud and marsh vegetation which are subject to tides and are of very limited use. Small sections have been drained for crop production, but the problem is complex and the drainage practice has been applied to only a very small area. However, the marshes are very valuable as habitat for fur-bearing muskrat and other wildlife.

The highly variable soil materials of the Coastal Plain were transported from higher elevations of the Atlantic slope and deposited in layers or unconsolidated beds. The deposits are thought to be a mixture of marine alluvial and glaciofluvial materials.

Greater slope to seaward occurs in the more elevated western

part of the area than in the seaward portion, which is nearly level. The textural composition of the deposits varies from coarse gravels to fine clays. The surface varies from sands to silty clay loam. The sub-soils are sands to plastic sticky clays. Soils with fine texture throughout the profile are usually wet, but in places where surface drainage is provided, they can be used for crops that are somewhat tolerant of reduced soil aeration. Because of the effects of climate and parent materials, the soils are mostly acid under natural conditions.

The Coastal Plain consists of two major sub-divisions, an inner and an outer area. The separation zone follows a wavy arbitrary line and is somewhat vague because of complex interspersal of soil types. The greatest distinction between the inner and outer areas is the degree of sandiness and the extent of the clay strata. The inner Coastal Plain contains a greater proportion of fine materials in the soils. To a greater degree, sub-soils are heavier than surface layers and substrata. These finer textures increase the fertility and moisture retention of these sandy inter-coastal soils.

The outer Coastal Plain is relatively droughty and low in fertility because of the greater extent of deep, sandy soils. Although both the inner and the outer areas have wide flats of wet land, the extent of marsh and swamp is greater in the outer area.

Among the well-drained soils are Sassafras, Collington, Golts, Butlertown and Christiana. The soils having imperfect or poor drainage are Keyport, Woodstown, Fallsington and Elkton.

Vegetable crops are the principal crops of the Coastal Plain. Due to the influence of the Delaware and Chesapeake Bays and the Atlantic Ocean, the climate is moderate. The combination of soils and climate of the area lends itself to a wide diversification and a quick change in the pattern of cropping. It is the most productive area of the Basin for timber growth but, except for the wet areas, timber has been cut and replaced with higher valued crops.

SECTION III - LAND CAPABILITY CLASSIFICATION

3-01. DETERMINATION OF CAPABILITY CLASSES AND DEFINITIONS

The land capability classification is a systematic arrangement of different kinds of soil according to those properties that limit or restrict the use or determine the ability of the land to produce permanently without deterioration. The units used in classifying land are characterized by differences that significantly affect conservation practices, use suitability, crop yields and management requirements. Suitability for cultivation is assumed to include the use of machinery, at least of plows, tillage implements and harvesting equipment, and capacity for a significant yield of one or more crops with suitable treatment and protective

measures. In interpreting what the land can do and what it needs, each soil characteristic is considered in relation to all others.

Soil characteristics and qualities that have been found most generally to be meaningful are given below.

1.	Effective depth of soil	9.	Natural soil drainage
2.	Texture of surface soil	10.	Inherent fertility
3.	Permeability of sub-soil	11.	Organic content
4.	Permeability of sub-stratum	12.	Slope
5.	Thickness of surface soil	13.	Erosion
6.	Thickness of sub-soil	14.	Wetness
7.	Available moisture capacity	15.	Salinity
8.	Acidity	16.	Frequency of inundation
		17.	Structure

With these facts and a knowledge of the climate of the area, the land can be classified according to its capability, its ability to produce permanently under specified uses and treatments.

The degree of permanent limitation imposed by effect of soil characteristics and qualities necessarily affects: (a) the number and complexity of the corrective practices; (b) land productivity; and (c) intensity and type of land use.

The capability classification is made and used for a practical purpose, which is the selection and application of land uses and treatment that will: (a) use the land, and (b) keep it in condition for long-time production. The latter involves the application and maintenance of conservation practices.

There are eight land capability classes,1/ four of which are suited for cultivation. Classes in this category are differentiated according to the degree of permanent limitation in land use that is necessary because of natural land characteristics. They are, therefore, correlated with the general level of treatment or corrective practices needed.

The eight land capability classes range from the best and most easily farmed land, with the least limitation in use (Class I), to land suitable only for wildlife habitat, recreation or protection of watershed values (Class VIII).

<u>Land Capability Class Definitions</u> -

CLASS I land is suitable for cultivation with no special

1/ For specific local definition, see the Technical Guide in the local Soil Conservation District.

conservation problems. It is nearly level, with deep well-drained soils which need only ordinary good farming practices to maintain soil structure and organic matter.

CLASS II land is suitable for fairly intensive cultivation but needs some simple conservation treatment or has some natural limitation on its use.

One example is gently sloping land that needs strip cropping and simple water management practices. Another is land with fairly good drainage but not good enough for best yields of crops which require good drainage.

Proper selection of crops, following good rotations and maintaining soil organic matter, helps in the conservation farming of this land.

CLASS III land is suitable for cultivation but needs intensive conservation practices--for example, moderately sloping land that needs strip cropping supplemented by diversion terraces and a fairly long rotation or wet land which needs drainage if it is to be used for cropland.

It also includes shallow soils where crop production frequently is limited by the low moisture capacity.

CLASS IV land has very severe limitations in use. It is suitable for hay or pasture and limited cultivation. An example is moderately steep, eroded land that needs thorough protection from erosion. Other land in this class includes wet land which will grow some hay crops but is too wet for cultivation in most years. It may also have frequent outcrops or ledges to make plowing difficult.

CLASS V land has natural features that make it more suitable for use as pasture, forest or wildlife habitat than to cultivation. Soils of this class occur on nearly level areas and are often wet and may be very stony. Conservation practices can be limited to those which maintain a desirable cover. Very little of this type of land occurs within the Basin.

CLASS VI land is best adapted to pasture, timber production and wildlife. Soils of this class have pronounced features of steep slopes, severe erosion hazards, stoniness, shallowness, wetness or droughtiness. Conservation practices are necessary on pasture and wildlife areas. The forested lands require sound forest management practices to accommodate the pronounced physical limitations of this land class in order to maintain favorable watershed conditions.

CLASS VII land differs from Class VI largely in the severity or complexity of the pronounced features of steep slopes, severe erosion hazards, stoniness, shallowness, wetness or droughtiness. It is best adapted

to commercial timber production, recreation and wildlife habitat uses. It is usually unsuitable for improved pasture. Carefully designed forest management practices are essential to maintenance of favorable watershed conditions.

CLASS VIII land is characterized by very rocky, steep slopes, mining wastes, marsh land, gravel bars along rivers and creeks, and large quarries. This class of land may be suitable for wildlife habitat, recreational uses, or as protection forest for the purposes of watershed management.

Land which has been classified according to the above definitions indicates its potentialities and limitations. The classification based on the information obtained from soil surveys is used for the preparation of a physical land inventory which is essential to sound planning and lasting conservation and resources development.

SECTION IV - LAND CAPABILITY CLASSES

4-01. DISTRIBUTION OF LAND CAPABILITY CLASSES

The distribution of land use in the Delaware River Basin according to land capability classification is shown in Table 12. Examination of the data shows that Classes I, II and III, which include most of the land suitable for cultivation, make up 46 percent of the Basin. Further examination will also show that of the 46 percent, 3.2 percent is Class I; 21.5 percent is classified as Class II; and 21.4 percent is classified as Class III. The two other large areas are Class VI, with 14.2 percent, and Class VII with 19.2 percent.

The distribution of land capability classes by physiographic regions is shown in Table 13. It will be noted from this table that the distribution for each physiographic region generally parallels and is very similar to the distribution for the Basin. However, in Physiographic Region 3, the Classes I, II and III make up 60 percent of this Region compared to 46 percent for the Basin.

TABLE 12. DISTRIBUTION OF LAND USE ACCORDING TO LAND CAPABILITY CLASSIFICATION
DELAWARE RIVER BASIN

Class of Land	Amount in Basin	Cropland	Pasture	Woodland	Idle[1/]	Urban	Total
	Percent	Acres	Acres	Acres	Acres	Acres	Acres
I	3.2	151,096	19,945	60,108	13,898	12,639	257,686
II	21.5	1,095,384	162,282	354,520	124,103	25,367	1,761,656
III	21.4	841,603	156,416	609,612	126,479	15,693	1,749,803
IV	8.7	221,270	30,716	415,291	31,589	8,792	707,658
VI	14.2	102,722	49,842	974,368	27,869	4,979	1,159,780
VII	19.2	55,653	27,628	1,448,549	33,914	2,621	1,568,365
VIII	2.0	2,391	794	126,352	33,346	3,435	166,318
Unclassified*	9.8	—	—	—	119,660	678,674	798,334
Total	100.0	2,470,119	447,623	3,988,800	510,858	752,200	8,169,600
Percent	(100.0)	(30.2)	(5.5)	(48.8)	(6.3)	(9.2)	(100.0)

1/ May include valuable wildlife wetlands.
* Cities, roads, water and other.

TABLE 13. DISTRIBUTION OF CLASSES OF LAND ACCORDING TO CAPABILITY CLASSIFICATION, BY PHYSIOGRAPHIC REGIONS DELAWARE RIVER BASIN

Class Of Land	Physiographic Region 1		Physiographic Region 2		Physiographic Region 3		Total
	Acres	Percent	Acres	Percent	Acres	Percent	Acres
I	83,870	2.4	60,461	2.1	95,772	5.4	240,103
II	466,347	13.1	682,266	23.8	488,613	27.9	1,637,226
III	508,035	14.3	648,243	22.5	467,344	26.7	1,623,622
IV	395,093	11.1	236,131	8.3	24,595	1.5	655,819
VI	655,761	18.5	385,676	13.4	31,058	1.7	1,072,495
VII	862,185	24.3	385,570	13.4	201,539	11.6	1,449,294
VIII	958	.1	5,515	.2	147,249	8.4	153,722
Unclass-fied	575,047	16.2	468,062	16.2	294,210	16.8	1,337,319
Total	3,547,296	100.0	2,871,924	100.0	1,750,380	100.0	8,169,600

USE AND MANAGEMENT OF LAND AND COVER RESOURCES OF THE DELAWARE RIVER BASIN

CHAPTER III

PRESENT COVER AND USE

SECTION I - INTRODUCTION

Present cover and use of the land in the Delaware River Basin is influenced by a number of factors. The soils, topography and climate are largely responsible for varied agricultural uses between the three physiographic regions of the Basin. These factors, together with the pressure of urban and industrial expansion, are responsible for the conversion of land to nonagricultural uses.

Table 14 shows the proportion of each of the major land uses in the Delaware River Basin. About 70 percent of the harvested cropland was in pasture and hay crops in 1950, according to the Census figures. It will be noted from the table that 9.2 percent of the Basin is in urban area.

Because much of the land in the Basin is devoted to the growing of hay, pasture and small grains, the number of months that the land is without effective cover is at a minimum. The average annual rainfall is fairly uniform in seasonal and geographic distribution over the Basin from north to south. Slightly more than half of the annual rainfall occurs from April through September, when the cultivated land is most vulnerable to severe erosion and run-off.

In general, the forests of the Delaware River Basin are young and are characterized by a high percentage of seedling and sapling size stands and unstocked areas. Less than one-third of the area has as much as 1,500 board feet per acre in trees of sawtimber size, the minimum stand considered feasible for commercial operation. Of this one-third, only one-fifth, or less than 7 percent, of the total forest area of the Basin is in stands that have as much as 5,000 board feet per acre. These figures should be compared with the 7,500-10,000 board feet per acre which should be the potential for this country. Annual growth rate on this forest is estimated to be from one-fourth to one-half of its potential.

There is a wide diversity in the natural type and composition of the forest areas due to the range in climate, topography and soils. The types range from spruce on the podsol soils, through northern hardwoods and mixed oaks to loblolly pine on coastal sands along the lower Delaware. Past unmanaged cutting, fire and other abuses have modified these types so that many stands now contain species and cull trees inferior both for timber production and for creating good watershed conditions (Table 15).

Competition for agricultural lands is not uniform throughout the Delaware

TABLE 14. PROPORTION OF MAJOR LAND USES
DELAWARE RIVER BASIN

Land Use	Portion Of Total	
	Acres	Percent
Cropland	2,470,119	30.2
Pasture	447,623	5.5
Woodland	3,988,800	48.8
Idle	391,198	4.8
Urban	752,200	9.2
Marsh And Water Area	119,660	1.5
Total Land And Water Area	8,169,600	100.0
	(12,765 sq.mi.)	

TABLE 15. PRESENT FOREST ACREAGE BY PHYSIOGRAPHIC REGIONS BY TIMBER TYPES AND STAND SIZE
DELAWARE RIVER BASIN

Timber Type	Acres	Physiographic Region 1				Physiographic Region 2				Physiographic Region 3			
		Heavy Saw-timber	Light Saw-timber	Poles	Seedling And Sapling Nonstock	Heavy Saw-timber	Light Saw-timber	Poles	Seedling And Sapling Nonstock	Heavy Saw-timber	Light Saw-timber	Poles	Seedling And Sapling Nonstock
	(000)	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres	Acres
Hardwoods	1,364.0	47.8	182.8	465.0	280.0	18.3	61.8	59.5	89.0	19.2	22.4	52.7	65.5
Softwoods	370.8	4.1	16.4	42.7	28.7	6.4	20.7	20.3	30.2	24.2	28.2	66.4	82.5
Mixed	363.5	10.4	40.7	105.9	70.6	.4	1.0	.9	1.7	15.8	18.5	43.5	54.1
Oak-Hickory	1,595.4	30.6	128.2	351.9	284.6	43.0	169.9	149.1	236.8	24.2	28.2	66.4	82.5
Other	295.1	11.8	48.8	132.2	102.3	—	—	—	—	—	—	—	—
Total	3,988.8	104.7	416.9	1097.7	766.2	68.1	253.4	229.8	357.7	83.4	97.3	229.0	284.6

River Basin. Because of the effect of the conversion of agricultural lands to nonagricultural uses on agriculture, water supply and sediment problems, a study was made to determine the magnitude of this trend to nonagricultural uses in the Basin.

It is recognized that study of a few sample areas would be inadequate from requirements for statistical significance, but it is also recognized that use of precise statistical sampling techniques covering the Delaware River Basin were beyond the resources of the present study. It was essential to find areas where significant amounts of change had occurred within reasonably compact areas. Areas representing types of change, types of farming, and typical topography were selected for which suitable air photo coverage and Census data for minor civil divisions were available.

Techniques of air photo interpretation, perfected for studies of land clearing and drainage development 1/, were adapted to needs in the present analytical problem of shifts from agricultural to urban land uses. The years when the coverage occurred varied from county to county but, generally, the prewar flights were made in 1937 or 1938 and the postwar flights were in 1954 or 1955.

The comparison studies of land clearing mentioned above were made for townships by stereo photo interpretation study of 1:20,000 contact prints. To study each county in its entirety would have required more time and funds than were available. An adaptation of the contact print method was developed, using the photo index sheets at a scale of about 1 inch to the mile. By comparing the early and late index sheets, the areas of change in land use were identified and outlined on the latter sheets. The areas of change were then checked on the contact prints which provided greater and clearer detail.

The areas of change then were measured and the acreage computed. At the same time, the soil type for each area of change was obtained from the county soil survey report. Three main classes of soils were used: well-drained, moderately well-drained, and poorly drained.

A field check of the area studied indicated that the estimates from photo interpretation of the shift from agriculture to urban were conservative. Several farms bore signs indicating that they had been sold and were available for real estate development. These are still in operation pending urban or industrial development. Such tracts were interpreted as being farmland in production, although agricultural use might cease at any time.

1/ Dill, H. W., Jr., Land Clearing and Drainage Data from Air Photo Interpretation, Agricultural Economics Research, USDA and Cooperating Agencies, Vol. IX, No. 3, July 1957.

Sample counties and secondary areas were studied in detail to provide guides for adjusting growth rates between service areas. Bucks County, Pennsylvania, New Castle County, Delaware, and the significant areas of Burlington County, New Jersey, were covered entirely by aerial interpretation and study of Census data. Urban areas of Dover, Delaware, Bridgeton, New Jersey, and Allentown-Bethlehem-Reading-Easton in Pennsylvania also were studied by photo interpretation. These samples provided limited guidance for projecting distribution of future growth between service areas.

SECTION II - COVER CONDITIONS

2-01. PRESENT COVER CONDITIONS BY PHYSIOGRAPHIC REGIONS

Physiographic Region 1

The northern part of the Basin has a short, cool growing season. In years of early killing frosts, corn does not mature. Although the climate is favorable for small grains, the physical characteristics of the land limit the acreage of these crops. Many fields are small because of the rough terrain. Labor-saving machinery and equipment have limited use because of steep slopes, stoniness and poor drainage. Farming in this Region, therefore, is mainly devoted to dairying, with a high percentage of the area in woodland.

Proportions Of Each Land Use - Physiographic Region 1

Land Use	Percent Of Total
Cropland	15.9
Pasture	4.8
Woodland	71.3
Idle	2.8
Urban	5.2

Cropland -

The cropland makes up about 16 percent of the region. The crops grown are suitable to support the dairy enterprise. A typical rotation is corn, small grain and several years of hay.

Corn is grown in the valleys or on the more gently sloping uplands. About 80 percent of the corn is cut for silage and used for winter feed and roughage.

The total acreage in small grain is slightly greater than that of corn. About 10 percent of the harvested cropland is in oats and 2.5 percent in wheat. Because of the rather severe winters, winter barley and rye are minor crops.

Oats, generally, give a low return per acre, but are quite popular as a companion crop in establishing new hay and pasture seedings. Since oats are spring sown, in most instances they can be conveniently grown in rotation with corn in the higher altitudes of the Basin where the growing season is too short to grow a good crop of corn and then to establish a winter small grain. Winter wheat is also used as a companion crop for seeding hay and pasture mixtures.

The yields of most of the grain crops are lower in the specialized dairy area than in areas of general farming and cash-crop farming.

Hay and Pasture Land -

Hay and pasture crops are important in supplying the feed for dairying.

Pasture occupies part of the cropland, with some areas set aside for permanent grazing. The permanent pasture accounts for about 5 percent of the region.

About 70 percent of the hayland area was in clover and timothy in 1950. Slightly more than 6 percent of the total hay acreage was devoted to alfalfa. The remaining 24 percent of the hayland was seeded to miscellaneous hay mixtures.

Woodland -

There are two distinctly different forest areas in this region. The first (designated as B8c and B8d in Fig. 10 of Chapter II) lies roughly north of a line running east and west through Stroudsburg. This is a country of generally rugged topography with long steep slopes. The climate and soils are favorable for timber growth and the productive potential is high. The northern hardwood type (beech-birch-maple) predominates on about half of the area, mainly on the more acid soils. An area roughly corresponding to the headwaters of the Lehigh River in Luzerne, Lackawanna, Carbon and Monroe Counties is now largely covered with scrub oak. Here the occurrence of this nearly valueless timber type, on these productive sites, is mainly the result of past over-cutting and destructive fires. The remainder of the forest in the area is composed of mixed hardwood-softwood and oak-hickory stands. These are somewhat lower in productive potential than the beech-birch-maple stands but are still capable of producing important amounts of timber under good forest management.

The physical conditions that have produced the northern hardwood type are also those favorable for dairy farming and the two closely coincide. Most of the 125,000 acres of grazed woodland in the Basin is in this type. This grazing has reduced the forest productivity and watershed efficiency of these lands through the effects of browsing and soil trampling.

The predominance of young stands (25 percent), with their undeveloped humus and litter, indicates a relatively slow recovery for good watershed condition. However, with the exception of the scrub oak and the grazed acres, the forests of this area are generally in such condition that improved management would yield rapid gains toward reaching their productive and other use potentials.

The second of the significant forest areas (B14b in Fig.1) in this region corresponds closely with the anthracite coal area of eastern Pennsylvania. Like other parts of this Physiographic Region, the topography is rugged and the slopes long and steep. In contrast to the rest of the region, the forest soils here are thin and rocky, and the productive potential is much lower. The principal timber type is oak-hickory, and the stands typically have many fewer trees per acre than on the better sites.

In addition to a naturally inferior stand, the forests of this area have received severe use and have been subjected to many fires. As a result, although three-quarters of the area is classed as forest land, about one-fifth of this is in scrub oak and aspen-grey birch types, and 90 percent of the forest is in young or understocked stands.

Idle Land -

The idle land in this Physiographic Region amounts to about 3 percent of the region. It is the rougher land that cannot be farmed with modern machinery. The continued substitution of tractor for horses as the main source of farm power has made available for dairying and other uses a substantial acreage that in the past was needed to provide feed for horses. Mechanization has made it more profitable to farm the best land more intensively and to use the roughest cropland for permanent pasture. These changes have also encouraged leaving idle the land which is hardest to farm. Part of the idle land is being held in estates or as potential real estate development.

Urban -

The urban area in Physiographic Region 1 amounts to about 5 percent of the region. Urban expansion has not been as great in this region as is occurring elsewhere in the Basin. Except for such cities as Honesdale and Stroudsburg, the majority of the towns are relatively small.

Physiographic Region 2

Agricultural production is diversified in Physiographic Region 2. Diversification fits the area well because of the less rugged topography and the well-drained, productive soils. The more gentle slopes lend themselves to the use of labor-saving machinery and equipment. General farming, dairying and livestock production are the leading enterprises.

Some specialty crops, such as tomatoes for canning and landscape nurseries, occupy some of the land. The woodland is mostly found on areas that are rough or where the soils are somewhat shallow.

Proportions Of Each Land Use - Physiographic Region 2

Land Use	Percent Of Total
Cropland	44.7
Pasture	8.0
Woodland	32.0
Idle	6.0
Urban	9.3

Cropland -

The area in cropland in this region is almost 45 percent. Dairying and general farming are the principal farm enterprises, with some specialization in potatoes and fruit in Lehigh and Northampton Counties. In addition, there are many local areas which produce peas and tomatoes for canning. Grain is an important cash crop. Both corn and winter wheat are used in the rotations much more extensively than in Physiographic Region 1.

Hay and Pasture Land -

Hay and pasture land occupies much of the cropland in this region. The abundance of well-drained soils in this region, together with higher natural fertility, supports high quality grass-legume mixtures. Alfalfa is grown both in the rotation mixture and as a long-term hay crop. About 8 percent of the region is set aside for permanent pastures. These are usually the steeper or rocky areas where native grasses furnish good grazing in early spring and late summer. However, in recent years, some farmers are seeding tall grass and legume mixtures in their permanent pastures.

Woodland -

In this region, most of which is now or has at one time been in farms, the woodlands are mainly in small woodlots. For the most part, these are along the ridges or on the sites too wet or too stony for farming. The principal exception to this situation is in Sussex and Warren Counties, New Jersey, where forests cover extensive areas along the highlands bordering the Delaware River.

The forest types are principally oak with a mixture of the faster growing hardwoods on sites where deeper soils and better moisture conditions will support their growth. There is also a considerable acreage of eastern red cedar that has come in on abandoned pasture lands. The

condition of the forest stands varies from good to very poor, depending largely on the manner of past cutting and on whether or not they have been grazed by domestic stock. The percentage of the total forest area classed as sawtimber is higher for this section than for any other in the Basin, running nearly one-third.

Although the forest area in this section is relatively small, most of these forest stands occupy strategic positions on the hillsides where soils are thin and run-off is rapid. Better management and protection from grazing would do much to stabilize flows from these hillsides.

Idle Land -

The idle land in Physiographic Region 2 accounts for about 6 percent of the region. This is mostly land that had been utilized for farming at some time in the past. However, stoniness and low fertility have led to land abandonment so that agriculture has decreased. Much of this land is being held for industrial expansion and suburban development.

Urban -

The urban area in Physiographic Region 2 amounts to about 10 percent. Urban expansion has been greater in this region than any other part of the Basin. The Cities of Allentown, Philadelphia and Bethlehem are in the region, with Wilmington and Trenton just outside. If present day trends continue, and if most of the ideas of the various city and county planning agencies are carried forward, there will be vast changes in land use and cover type. The built up urban-industrial area has and still is increasing tremendously.

The physical changes are obvious. This urban expansion has brought with it new roads, bridges and highways. Just north of Philadelphia, the Pennsylvania Turnpike is cutting across the countryside to the north, east and west. The Schuylkill Expressway is moving south from the Turnpike to central Philadelphia. At Trenton, a new freeway is carrying traffic around the city's crowded center from the Morrisville-Trenton toll bridge. All of these changes are altering the physical face of the landscape and replacing vegetative cover with roofs, concrete and asphalt.

Bucks County, Pennsylvania, residents resisted urbanization more or less successfully until after World War II. Their land use pattern was molded in part by estates and other ownerships not dependent on commercial farming, although many first-class commercial farms were operated in areas of better soils.

The explosion of population, construction of the Fairless Steel

Plant, and extension of rapid transport routes for autos and busses in portions of the county brought overwhelming economic pressures on the former status quo.

Change came in spite of local sentiments and before local residents could prepare for it. Whole sub-divisions, new shopping centers, new roads appeared almost overnight in lower Bucks County. In the central area of Bucks County, development of single units or small clusters of rural residences have complicated land management programs.

Study of aerial photos taken in 1938, 1950 and 1954 indicates that 5 percent of total Bucks County acreage had been converted to urban use during the sixteen-year period. Another 12 percent of the county is encroached by urban uses and in process of transition to nonfarm uses. When these proportions are added to the more than 9 percent of the total area that was urban prior to 1938, we see that 13 percent now is urban and 12 percent is encroached. This means that a quarter of Bucks County is urban or probably will be in the foreseeable future. The effects of urbanization extend far beyond the physical boundaries of tracts used for housing or industry.

Greatest change, of course, has occurred in lower Bucks County where 14 percent of the land was converted to urban use during the period 1938-54. Coupled with the 13 percent of the area that was urban prior to 1938, we find 27 percent of lower Bucks County now is urban and another 18 percent is encroached.

About 21 percent of the county area in 1954 was cropland in transition to some other use. This varied from 22 percent in lower Bucks County to 19 percent in central Bucks and 20 percent in upper Bucks. However, reasons for the transition phase varied considerably.

On a county-wide basis, Bucks County has experienced continued decline in production of hay, small grains, potatoes and vegetables. Acreages of corn and soybeans for all purposes about held their own between 1945 and 1954.

Growth of Reading, Pennsylvania, during the period 1947-1955 affected about 10,500 acres of agricultural land, 3,072 acres entered urban additions, 7,328 acres were encroached by urban-industrial expansion, and 112 acres were taken for new roads.

Cropland, mainly from the lands on the valley floor, accounted for about 66 percent of the area taken for urban growth, 10 percent came from cropland encroached before 1947, and the remaining 24 percent came from pastures. Cropland and pasture land furnished the area for new roads.

The 7,328 acres presently encroached, which will provide the logical space for further expansion, is divided among present uses as follows:

70 percent cropland and cropland in transition to nonfarm uses, 24 percent pastures and pasture in transition, and the remaining 6 percent is in forest.

The Pennsylvania Cities of Allentown, Bethlehem and Easton lie along the Lehigh River in the upper Piedmont of the Delaware River Basin. Easton, lying at the confluence of the Lehigh with the Delaware, is considerably smaller than its sister cities, partly because it must share activity with Phillipsburg, New Jersey, lying directly across the Delaware River from it.

All of these cities had their beginnings oriented to the relatively level lands along the stream valleys, and direction of growth to the present has been affected by the rough terrain adjoining the towns. Previous locations of steel plants and railroads have been effective limitations on direction of growth due to smoke, fumes and dirt carried by the winds.

An area of 45,520 acres was studied by photo-interpretation to ascertain nonfarm growth during the period 1947-55. New roads had taken 720 acres (2 percent) during the period, built up areas had taken 8,976 acres (20 percent), and another 12,160 acres (27 percent) were encroached by houses and factories.

We can be reasonably certain that growth in the near future will be largely along lines already established. Thus, a high proportion of the presently encroached area will provide land for the new urban areas. Exceptions to this generalization will occur as new routes for highways develop or as new factories and shopping centers may be located outside the present pattern.

Thus, where Allentown has grown southward along Highway 29 into farming areas lying between it and Emmaus, and north of town into areas adjacent to Highway 22, future growth probably will have to be absorbed by the remaining cropland and idle cropland encroached or already in transition to urban uses.

Growth of Bethlehem has been mostly onto farmland north of town, lying between the city and Highway 22 in Hanover Township. A few areas of housing and industrial uses have developed southward toward Hellertown on the lower slopes of the hills. Future growth in this area seems to be limited to rather steep topography around Hellertown. Again, the direction of future growth seems to be pretty well determined by the areas of agricultural lands already encroached and in transition. Part of Bethlehem's problem lies in the legal complications involved when a city crosses county line jurisdictions.

Most of Easton's recent growth has been west from town, between the Lehigh River and Seipsville. Future development probably will

continue north of Seipsville into Palmer Township and along Highway 22 in Bethlehem Township.

Physiographic Region 3

The Coastal Plain section, or Physiographic Region 3, is an important vegetable crop producing area. The occurrence of favorable soil, topography and climate conditions in close proximity to large centers of population has led to the development of specialized farming for the production of fresh vegetables, fruit and potatoes. The land is used very intensively for these crops, especially when two or three crops may be grown on the same piece of land in one season. Where soils are unsuited to vegetable production, corn and winter grain predominate.

Proportions Of Each Land Use - Physiographic Region 3

Land Use	Percent Of Total
Cropland	36.2
Pasture	3.4
Woodland	37.0
Idle	6.6
Urban	16.8

Cropland -

The area in cropland in this region is about 37 percent. The area can be designated as a specialized farming area for the production of fresh vegetables, fruits and potatoes. The lighter soils are used rather intensively. Cash grain farming is carried on in the area where the soils are heavier textured and less suited to the production of truck crops. There are many truck market garden farms found near the larger cities. There is also some part-time farming near the cities and larger towns. Some dairying is combined with both truck farming and general farming as cash grain farming.

Hay and Pasture Land -

Hay and pasture crops are grown to supply feed for dairying. The area set aside for permanent pasture accounts for only slightly more than 3 percent of the region. The balance of the pasture is part of the cropland. Much of the area is made up of light, sandy soils which are droughty and, therefore, the native grasses produce less forage and are subject to burning out in early summer. Due to the short rotations in use in the area, hay and pasture occupy the land for a much shorter period of time compared to the other two regions, particularly Physiographic Region 1.

Alfalfa is used as a cash crop on some farms where the owners are engaged in some other business and maintain the farm primarily as a home.

Woodland -

The Coastal Plain is generally of very gentle topography. Because it is an area of intensive truck and mixed farming, the forested areas are confined to the sites too wet or too dry for farming. About one-third of the region is forested.

Seventy-five percent of the forested area of the region is in poles and seedling and sapling stands.

About half is in softwood types (pitch, Virginia, short-leaf and loblolly pines) or mixed pine and oak. The other half of the forest stand is primarily in oak types, with a mixture of bottom land hardwoods on the better sites. Most of the pine and pine-oak mixtures are found in the southern part of the region along the coast line.

There is a tremendous variation in condition of the forest stands; most of them are fair or poor.

Heavy over-cutting and repeated fires are the major causes of this condition. In a few areas, this abuse has been so severe that the land has reverted to a scrub oak type.

Idle Land -

The idle land in this Physiographic Region amounts to about 7 percent of the region. It is principally of two kinds. One is that which has been abandoned because of wetness and low fertility; the o other is land that is not being farmed because it is being held for industrial and urban development. Much of the wet land borders on the tidal marsh areas, along the streams, the bays, and the Delaware River. However, much of this area provides valuable wildlife habitat.

Urban -

The urban area in Physiographic Region 3 is in the highest proportion of any of the three regions. The urban area consists of almost 17 percent of the area of the region. New Castle County, Delaware, leads the nation in population increase. A survey made by Public Service of New Jersey showed that in the past few years some 15,000 acres of land in Camden, Burlington, Gloucester and Mercer Counties have been assembled by the builders to hold 50,000 new dwellings. The Brookside-Chestnut Hill development outside of Newark,

Delaware, has a combined population making it, in effect, the fourth city in Delaware. This great expansion of urbanization has created whole new communities. This, of course, reflects the industrial expansion which is taking place.

Study of land use changes as reflected by comparable aerial photos of 1937 and 1955 shows that 9 percent of New Castle County's area changed in status from open country farming during the period; almost 6 percent changed from agriculture to urban uses; another 3 percent of the total area was seriously encroached and agricultural uses probably would cease within a few years; and 0.1 percent of the acreage was in transition stages between agricultural and urban-industrial uses.

Of New Castle's 1937 agricultural land base, urban dwellings and industrial structures covered 9 percent by 1954, and another 4 percent was seriously encroached by construction. Nine percent of the cropland had been taken for roads, houses, or other structures; and another 2 percent was encroached. Eighteen percent of cropland in transition from farming in 1937 had been converted to urban uses, and another 18 percent was encroached. Ten percent of the pasture land in 1937 had been changed to urban use and 3 percent more was encroached. Nearly 25 percent of pasture land, formerly in transition stages, now was in urban use or its use was imminent.

The former agricultural uses of the lands affected by urban growth were 72 percent cropland and 28 percent pasture. A small acreage of wooded area was absorbed by urban growth but its percentage of the total area was insignificant.

The Chesapeake-Delaware Canal cuts through the center of New Castle County and provides something of a physical division between the northern and southern portions. Practically no agricultural land from this portion of the county has been taken for urban or industrial uses. The DuPont Highway passes through some of the best farming area in the state, uncluttered by gas stations, motels, farm markets, or concentration of rural dwellings until it reaches the Smyrna-Clayton complex in northern Kent County.

The common observation that the best agricultural lands are most affected by urban expansion is borne out by the New Castle data. Analysis showed that 87 percent of the cropland taken for urban uses from 1940 to 1956 were well-drained fertile acreages suitable for irrigation, 6 percent were moderately well suited for irrigation cropping, and 7 percent were poorly drained and poorly adapted to agriculture. Since the new roads generally have been built to service the new communities, the proportions of farmland quality taken for roads fall roughly into the same pattern as those for cropland.

Analysis of Census data shows that farms north of the canal are

concentrated in the smaller sizes. Average size of farm increases with distance west and south of the county. Some of the largest and best farms of the state are around Middletown, Delaware.

The Middletown area, reaching up toward Delaware City, experienced growth of land in farms and in cropland harvested between 1945 and 1954. All other districts showed declines. Since 1954, an oil refinery at Delaware City has purchased several thousand acres, including several farms, and has built a plant. Some of the cropland not needed for present plant operations is being leased for agricultural use, but total production of the tract affected has been reduced.

In general, idle cropland has increased immediately around Wilmington and around the periphery of the county.

A supplemental study was made of the Bridgeton area in Cumberland County, New Jersey, to assess the urban development impact on a small sub-regional center in an area dominated by agriculture. Comparisons of land uses were made by study of air photos taken in 1940 and 1956.

An area covering 4,600 acres was found to include all but a few scattered developments. The limits of Bridgeton in 1940, together with roads in the area, accounted for 71 percent of the acreage. About 10 percent of the area, largely former cropland, had changed to urban use, 8 percent of the present cropland was in transition to urban use or seriously encroached by urban uses, and the remaining 11 percent was cropland or pasture.

Some changes in land use, due to urban influences, had occurred throughout the remainder of the Bridgeton trade area, but the amount would be statistically insignificant. Much more significant in present land uses have been changes in the economics of agriculture in Cumberland County. Numbers of farms declined nearly 20 percent between 1939 and 1954, land in farms declined 23 percent, but cropland harvested increased by about 5 percent. Nearly half of the farms having less than 50 acres of cropland and 25 percent of those having between 50 and 99 acres of cropland in 1939 disappeared by 1954. Increasing size of farm and the absorption of many small tracts of the better land is reflected in the increase of 21 percent in the number of farms containing more than 100 acres of cropland harvested between 1935 and 1954.

Adoption of modern farming methods and efficiency of size have helped many farm families maintain good farms in this county. Bridgeton and its sister city of Millville have had modest industrial expansion to date and anticipate even more rapid growth in the future. It would seem, however, that nonfarm construction probably will remain

more nearly centralized around the city core than it has further north in New Jersey.

Location of a large military air base a few miles from Dover, Delaware, during World War II removed several farms from production and created demand for additional housing and business sites in and near Dover. Examination of air photos showed that the changes of land use in this sector were confined largely to the area of the air base itself, the area immediately surrounding Dover, and, to some extent, the area between Dover and the base.

An area of approximately 9,600 acres covered the farthest extent of land use change. Within this area, 2,704 acres of cropland and 48 acres of pasture had changed to nonfarm use between 1938 and 1954. The air base accounted for 82 percent of this, urban growth for 15 percent, and roads and borrow pits for the remaining 3 percent. Nearly all of this area formerly was good, well-drained, fertile land suitable for irrigation cropping.

The Dover area is an illustration of a basically agricultural community where a relatively large user of land has come in and changed the picture for a small area but has not grossly affected the organization of the remainder of the area. Additional service facilities, housing and light industry, to date, have remained concentrated close to the parent city. Introduction of additional industries and accompanying housing and service areas probably will continue the present basic pattern with further outriders, or fingers, along the main arteries of travel. It is hard to visualize growth of heavy industry on this part of the Del-Mar-Va Peninsula in view of present and proposed transportation lines and the usual trends of freight traffic.

CHAPTER IV

PRESENT MANAGEMENT OF SOIL AND COVER

SECTION I - INTRODUCTION

Land cover, land use and management are three of the prime factors affecting run-off and erosion. They have a definite relationship to the amount of silt-free water coming from the land.

Each of the three physiographic regions has a combination of climate, soils and agriculture that tends to give it soil and cover management problems that differ. The soils and climate follow a rather definite regional pattern. This relationship and difference results largely from different elevations and latitudes. The combination of soils and climate sets limits on the kinds of crops that are advantageously grown and that largely determine the kinds of soil and cover management systems and problems.

SECTION II - PRESENT LAND MANAGEMENT

(Present use and cover of the land and the effect of urban and industrial encroachment upon this use was discussed in Chapter III.)

2-01. CROPLAND

In general, good management requires that organic matter be returned to the soil. This is accomplished through the use of crop residues, farm and green manures, an abundance of fertilizer, and as much lime as is needed to grow clover, alfalfa and other crops. The production of such close-growing crops as meadow mixtures, including legumes and the small grains in rotation, with the clean-cultivated crops, such as corn, is necessary to maintain favorable soil texture and structure.

It is commonly recognized that crop rotations aid in soil organic matter maintenance, weed and disease control and improved soil productivity. More recently, it has become evident that such practices improve the physical conditions of the soil, thus providing better aeration and drainage and reducing run-off and erosion losses. In general, however, the above factors have been only incidental in determining whether or not good crop rotations would be followed. Economic need has been the primary consideration. In general farming areas and on dairy and other specialized livestock farms, there is commonly a need for both grain and forage crops produced in a rotation. In these enterprises, cultivated crops are commonly grown in regular rotation with small grains and grass-legume mixtures.

On the vegetable and truck crop producing areas in the Delaware River

Basin, little or no livestock is kept on many of the farms. The replacement of horses, as a source of power by tractors and trucks, has removed all need for grass and legume crops as animal feed on these farms. In this situation, the decision as to whether or not cultivated crops will be rotated with sod crops rests on effects of such rotations on soil and water conservation, physical soil condition and on soil productivity. Many Coastal Plain areas have been cultivated continuously during recent years in the production of vegetable crops. Despite heavier fertilization and generally improved cultural practices, soil productivity has declined under this management in many cases. Also, a decline in structure has been evidenced by crust formation, increased run-off and erosion, impairment of drainage and shortages of soil moisture.

In recent years, grassland farming has increased in the dairying areas of the Basin. This system of farming emphasizes high quality forages in livestock feeding, with grain supplementing rather than dominating the feeding practices. This shift to more good cover on the land, together with good management, has had a tendency to reduce the erosion and run-off.

Much of the lands which are in grassland were not rich in their virgin state. They had been further depleted by erosion and loss of plant food from the forage removed from them. Thin stands of cover resulted, and their efficiency to reduce run-off and control erosion was reduced. Good management provides a cover to protect the soil against the beating action of heavy rains that cause run-off and loss of soil. The application of fertilizers and lime is essential for the production of a good cover and for good yields.

Experiment station results show that well-fertilized grass is effective in controlling sedimentation and in reducing run-off. With continuous cultivation, the percent of run-off and soil losses is high.

As it was pointed out earlier in this report, about 50 percent of the Basin is forested. Since the dairy industry requires large amounts of roughage, many steep slopes are in hay and pasture. These uses fit the areas well, and they have not contributed significantly to the management problems insofar as use is concerned. However, there is opportunity to improve management which will result in better protection to the land and improved hydrologic conditions of the watershed.

A recent survey indicated that the application of management practices to control water varies from about 1 percent of the area in the upper part of the Basin to about 20 percent of the area in the lower part of the Basin. These practices include pasture improvement, woodland improvement, establishment of perennial hay, contour strip cropping, waterways and outlets, and other management practices which are designed to make maximum use of the water for crops, livestock and by industrial and domestic consumers of water.

2-02. FOREST LAND

As will be seen in the discussion in Chapter V, the kind of management that the vegetative cover receives and the types of practices that are used in its manipulation play a very important part in determining the efficiency of this cover in regulating the run-off of water from the watershed. In general, the thrifty, well-stocked and highly productive timber stands that result from good forest management are also those best suited to waterflow regulation. It is important, therefore, to discover what the present management practices are, what the factors are that influence this management, and what the problems are that must be solved to provide better management.

a. Forest Land Ownership. Of the more than 3-1/2 million acres of forest land, 12 percent is in public ownership, largely state parks and forest and game lands; 23 percent is in farm woodlands, largely in the middle and lower Basin (mostly farm woodlots of less than 100 acres in extent); and 65 percent of the forest land is owned by other private individuals and companies. These latter owners include coal companies, lumber companies, people holding the land for possible speculation, and a very large number of summer home owners. Although no accurate figures are available, it is estimated that as much as one-quarter of the total forest land of the Basin is owned for recreational purposes and another 10 percent is being managed primarily for wild game production (Table 16).

Because of the great variety of reasons these different classes of owners have for possessing forest land, the degree of their interest in maintaining a productive forest cover varies widely. As a result, present management ranges from ignoring the timber cover completely, through some form of planned management on a small percentage of the land, to complete liquidation cuts where the owner is trying to realize the maximum immediate profit.

b. Recent Improvements In Management. There are several bright spots in the present forest management picture. As a result of a steady drive by the state forestry organizations of all the Basin states and cooperation by the federal government under authority of the Clarke-McNary Act, forest fire prevention and control is much improved. For the Basin as a whole, forest fires are no longer a major management problem. However, increasing effort and vigilance will be required to maintain this condition, especially in the face of predicted increases in use of forest land. Similar cooperative state-federal programs are in effect that are doing much to detect and halt the ravages of forest insect and disease epidemics.

Present laws in Pennsylvania require the rehabilitation of strip-mined lands. No longer will productive forest land be turned upside-down

TABLE 16. FOREST LAND OWNERSHIP
DELAWARE RIVER BASIN

Physiographic Region	Forest Land	Public Land	Private Land	
			Farm	Non-Farm
	Acres	Acres	Acres	Acres
1	2,385,438	276,948	532,494	1,575,996
2	909,099	54,605	239,691	614,803
3	694,263	90,254	215,222	388,787
Total	3,988,800	421,807	987,407	2,579,586

and left to produce sediment and unregulated run-off for years to come.

All of the Basin states have some form of law which permits the state forestry organization to give forest property owners technical assistance in tree planting, forest management and harvesting methods. Again, the federal government, under authority of the Clarke-McNary and Cooperative Forest Management Acts, is cooperating with the states in this work. In addition, financial assistance to the landowner for carrying out certain improved management practices is available through the Agricultural Conservation Program.

These programs made a disappointingly slow start but seem to be gaining in impetus. Estimates show that in 1952 about 5 percent of all timber cutting in the Basin was being done under technical direction. By 1957, the estimate had increased to 15 percent. This is still a long way from a desirable level but, nonetheless, is a very appreciable gain.

As livestock owners have learned of the inefficiency of grazing their herds in the woods and on steep, brushy, half-cleared pastures, this practice has gradually been reduced. As a result, many thousands of acres of steep thin-soiled hillside land, that formerly made little contribution to waterflow regulation, are now in far better condition. The 125,000 acres of such land still grazed constitute a critical problem in some minor watersheds, but this practice is no longer a Basin-wide problem.

c. Causes For Present Poor Management. Even with these improvements, there is still a widespread lack of good forest management. This may be attributed to a number of reasons, but the major factor is a lack of interest in good forest management on the part of the landowners.

The people who own forest land for recreation and resort use, typically, do not seem to care much what type of forest covers the land so long as it is green. For most of them, income from the land is of very small importance since they are usually urban dwellers not accustomed to thinking of land productivity, nor familiar with ways and means of improving it. Most of them have little appreciation of the role played by cover conditions and management in the regulation of waterflows. This same attitude is present to a considerable degree in the people who own and manage the land principally for the production of wild game.

Because of the present unusually high percentage of land in the Delaware River Basin that is owned for these purposes and because of predictions of even greater percentages in the future, attack on this attitude of indifference becomes a major management problem.

Owners of forest land who are interested in a return from the land and who might be interested in improving its productivity are plagued by the same economic problems that are common to forest landowners everywhere. Among these are: tax laws which penalize the owner who wants to defer cutting (an enabling amendment to the Pennsylvania constitution was passed in November 1958 in an attempt to improve this situation in Pennsylvania); failure by loan agencies to recognize productive forests as acceptable collateral, thus forcing liquidation to meet emergency needs for money; unwillingness of underwriters to sell insurance which would afford the owner some protection for his management investment against loss from fire, insects and disease; and high interest rates on money for improvements that must be carried for long periods of time until present young stands reach harvestable age.

In the Delaware River Basin, these common problems are aggravated by the fact that there are few market outlets for the small trees and inferior species that make up such a large part of the present stands. With adequate markets, the thinnings and sanitation cuttings needed to improve the forests could pay their own way. Without such markets, these improvements must be made with borrowed money that will not be returned until harvest cuttings are made in the distant future.

There are several reasons for the present lack of markets for such material. The few markets that do exist mainly use sawtimber which, as we have seen, is already in very short supply. The wood that must be moved to secure good management goes principally into round wood products (posts, mine props, fuel wood, etc.), or into pulp and chemical wood. The mine prop market has declined drastically, both with the decline in the coal industry and with more efficient mining methods that have reduced the amount of wood needed per ton of coal mined. Fuel wood and posts use only a small fraction of the supply, and even this small outlet is steadily declining. The chemical wood market (alcohol, charcoal, etc.) has never developed to any appreciable significance in the Basin.

The few extant pulp mills close enough to the Basin to draw on it for wood supplies use mostly soft woods - again, in short supply. A gradual conversion to the use of hardwoods for pulp is taking place but, as yet, is not nearly sufficient to consume the annual growth on the type of material that should be removed. Establishment of new mills within the Basin is hampered by lack of water supply or by the necessity for development of economically feasible pulping methods that will not pollute the streams into which the mill effluent must be drained.

SECTION III - COVER MANAGEMENT

3-01. COVER MANAGEMENT BY PHYSIOGRAPHIC REGIONS

Physiographic Region 1

Cropland -

In Physiographic Region 1, dairying has gradually assumed major importance as the farm enterprise. The field crops grown are primarily intended for the maintenance of the dairy industry and are selected with this in view. The general cropping scheme consists of corn (largely for silage), oats and hay. The hay is a mixture of timothy, clover, birdsfoot trefoil and some alfalfa. No hard and fast system of rotation seems to prevail. In recent years, with more widespread use of trefoil, the land is plowed much less frequently. This has brought about, largely, a grassland type of farming to the dairy country.

Due to elevation and climate, yields of most crops, except hay and pasture, are lower than in the other two physiographic regions. This is one reason why the region has become a specialized dairying area.

Where row crops are grown, they are usually confined to the valleys or on the more gentle slopes. Farmers who have limited fields of valley land put the fields in corn for several years in succession and apply enough manure and fertilizer to maintain soil productivity.

Contour farming and strip cropping have been used less extensively than they should be on the sloping land. This is due partly to the fact that, with hay and pasture occupying the higher percentage of the land, other methods of conservation farming have been more slowly accepted.

As might be expected, most of the cropland acres appear in the first three land classes. The first three land capability classes for this region total 29.8 percent of the area and represent 1,058,252 acres (Table 17). The area devoted to cropland amounts to 15.9 percent of the area, totaling 564,020 acres (Table 18). However, there are 92,255 acres in cropland in Classes IV, VI, VII and VIII. The use of these land classes as cropland presents difficult management problems. Because these lands are being used beyond their capability, they often are the source of high sediment production and high run-off. The principal need is to retire these lands from cropland to a use within their capability and manage them accordingly.

TABLE 17. CLASSES OF LAND ACCORDING TO LAND CAPABILITY CLASSIFICATION IN PHYSIOGRAPHIC REGION 1 DELAWARE RIVER BASIN

Classes Of Land	Acres	Percent Of Total
I	83,870	2.4
II	466,347	13.1
III	508,035	14.3
IV	395,093	11.1
VI	655,761	18.5
VII	862,185	24.3
VIII	958	.1
Unclassified (Cities, Roads, Water And Other)	575,047	16.2
Total	3,547,296	100.0

TABLE 18. PROPORTION OF EACH LAND USE IN PHYSIOGRAPHIC REGION 1 DELAWARE RIVER BASIN

Land Use	Acres	Percent Of Total
Cropland	564,020	15.9
Pasture	170,271	4.85
Woodland	2,529,222	71.3
Idle	99,324	2.8
Urban	184,459	5.2
Total	3,547,296	100.0

Hay And Pasture Land -

Present management of the hay and pasture lands in this physiographic region follows closely the grassland farming system. Hay and pasture mixtures are seeded in small grain, usually oats, and once established they are allowed to remain as long as the stand is considered productive. The forage is harvested for grass silage or hay, and the aftermath is often grazed. This type of management fits the area well and provides protection over a period of three or four years or more before the land is plowed for reseeding.

Fertilizers and lime have not been used as extensively as they should be in many cases. In those instances where fertility has been allowed to decrease, the cover is not as dense and often overgrazing results.

Woodland -

Present management of the forests in this physiographic region follows closely the general pattern for the Basin.

Because a large percentage of the forest recreation use of the Basin is concentrated here, especially in Wayne, Monroe and Pike Counties, Pennsylvania, and Sullivan County, New York, the management problems associated with this type of use and ownership are particularly important.

The scrub oak areas also present a special management problem since they often occupy sites that have a good potential for more valuable species. Once established, the scrub oak is particularly tenacious and conversion to a better type is both expensive and difficult. Feasible means of converting these stands are being studied through a cooperative research project by the Northeastern Forest Experiment Station of the U. S. Forest Service and the Pennsylvania Department of Forests and Waters.

Grazing damage, both by domestic livestock and by overpopulated deer herds, occurs in localized areas throughout the region. In the minor watersheds where this damage occurs, it is making a major contribution to flood and sediment damage. Its elimination is a problem that can be readily solved whenever the property owner's or the public's interest is sufficiently aroused.

Idle Land -

The present management of idle land in this physiographic region presents no great problem, except in the anthracite coal fields. In these areas, where stripmining has piled up large volumes of unprotected spoil, erosion has been severe. The material is often so acid

that natural vegetation will not grow on these areas. As a result, they continue to be a source of high sediment production and high run-off for many years unless they are stabilized by proper management.

Urban -

The urban areas in this physiographic region present few management problems that can be solved by agricultural programs. It represents only a small percentage of the region. The majority of the towns are relatively small, and their effect on the total area is relatively insignificant.

Physiographic Region 2

Cropland -

In Physiographic Region 2, present management of soil and cover is generally fitted to the diversified type of agricultural production that typifies the region. This region has the highest percentage of cropland of the three physiographic regions. Almost 45 percent of the area is devoted to cropland (Table 19).

The general cropping pattern consists of corn, 2 years of small grain and 1 or 2 years of hay. The hay is usually a mixture of timothy and red clover or alfalfa. With the diversified type of farming, good use is made of the hay as feed for dairy cattle or other livestock and, at the same time, the hay is very valuable in the rotation to maintain soil structure and organic content.

Contour farming and strip cropping have not been used as extensively as they should be on the sloping land. Whereas, in Physiographic Region 1 the row crops were confined to the more level bottom land and valley floors; in this region, row crops are grown on the sloping land as well. Even though the land is considered to be only gently sloping, many fields have slopes up to 600 or 700 feet in length and where they are not protected by strip cropping or by diversion terraces, serious erosion and run-off has been the result.

As was pointed out above, almost 45 percent of the region is classified as cropland, which amounts to 1,283,750 acres (Table 19). The total percentage of Land Classes I, II and III is 48.4 percent and amounts to 1,390,970 acres (Table 20).

There are 236,399 acres of cropland on Land Classes IV, VII and VIII. The present use is beyond the capabilities of this land and, as was pointed out for Physiographic Region 1, these areas are often the source of sediment and increased run-off.

TABLE 19. PROPORTION OF EACH LAND USE
IN PHYSIOGRAPHIC REGION 2
DELAWARE RIVER BASIN

Land Use	Acres	Percent Of Total
Cropland	1,283,750	44.7
Pasture	229,754	8.0
Woodland	919,016	32.0
Idle	172,315	6.0
Urban	267,089	9.3
Total	2,871,924	100.0

TABLE 20. CLASSES OF LAND ACCORDING TO LAND CAPABILITY
CLASSIFICATION IN PHYSIOGRAPHIC REGION 2
DELAWARE RIVER BASIN

Classes Of Land	Acres	Percent Of Total
I	60,461	2.1
II	682,266	23.8
III	648,243	22.5
IV	236,131	8.3
VI	385,676	13.4
VII	385,570	13.4
VIII	5,515	.2
Unclassified (Cities, Roads, Water And Other)	468,062	16.2
Total	2,871,924	100.0

Hay And Pasture Land -

Present management of the hay and pasture lands in this physiographic region follows the grassland farming type of management on the rougher areas and the more generalized type of management on the more gentle slopes. The main difference here is that the rougher areas are left in permanent cover and receive little or no management or treatment. On the more gentle areas, the hay and pasture is renewed more frequently through the regular rotation of crops. Two of the factors that influence this type of management and use are: first, grain and potatoes are grown as cash crops and, second, there is not the great demand for forages here as there is in Physiographic Region 1.

Fertilizers and lime have not been used as much as they should have been in this region. In spite of the fact that many of the soils in this region have been formed from calcareous material, continuous use without the addition of lime has lowered the pH to the point where it is now difficult to establish legumes. The effect of this has been shown in the reduction of organic content and deterioration of soil structure. Overgrazing, too early spring grazing, and too late fall grazing have also contributed to poor stands of cover. Good pasture management has been adopted slowly.

Woodland -

Although this region is essentially a farming area, only about one-quarter of the forests are in farm woodlots. The remainder are also mainly in small tracts but are owned by a great variety of people, many of whom have little or no interest in the timber or water producing ability of the land.

The ownership pattern probably accounts, in part, for the fact that the percentage of stands in the sawtimber sizes is greater than for any other region. Many of these woodlots are a part of rural estates or other holdings whose owners have little interest in income from the land and who have let the woods go uncut and unmanaged for many years. A high percentage of nonstocked and seedling and sapling stands are now present. This, plus the seemingly paradoxical fact that over one-half of the sawtimber cut in the Basin in 1955 came from this region, indicates that cutting is very heavy when it is done.

The principal forest management problems are to secure conversion to more productive types of red cedar stands that now occupy many abandoned pasture lands, planting on nonstocked idle farm land, and the introduction of better general management and cutting practices. Solution to each of these problems depends in large part on developing the property owner's interest in good management.

Idle Land -

The presence of a limited acreage of idle land in this physiographic region presents no outstanding problem. Those areas which have been abandoned have grown up to weeds or other forms of natural vegetation which are giving some protection to the land.

Urban -

The management of the urban area in this physiographic region presents quite a problem. The huge amount of land that has been converted from areas of good cover to areas of roofs, paving, or other poor hydrologic conditions totals thousands of acres. The results have been seen in flash floods where run-off has caused damage in areas where little or no damage was experienced until the areas were developed. In many places, stream channels and bridges have become inadequate to carry the additional storm water. Back water and out-of-bank flows have contributed to the damages.

Physiographic Region 3

Cropland -

In Physiographic Region 3, present management of soil and cover is generally inadequate to control erosion on the highly erodible soils. The land is intensively farmed, especially where truck crops are grown. Because there is little need for forage, hay is not grown extensively. Much of the land is continuously cultivated. This, together with the fact that this region has a rather mild climate, causes organic matter to burn out quite rapidly. As a result, soil structure is adversely affected and increased run-off and erosion occur.

About 36 percent of the region is devoted to cropland, which amounts to 633,637 acres (Table 21). The total percentage of the Land Classes I, II and III is 60 percent and amounts to 1,051,629 acres (Table 22). There are 26,781 acres of cropland on land classified as IV, VI, VII and VIII, with about one-third of this amount being on Class IV land. The use of these land classes as cropland is beyond their capability. A high percentage of the land classified in these four classes is so classified because it is either wet or droughty. Cover management has not received the attention it should to protect these soils. However, in recent years, more attention has been given to sod crops to be used as land resting crops. As was pointed out in the earlier discussion, this has become necessary to maintain yield, structure and organic content of these soils.

TABLE 21. PROPORTION OF EACH LAND USE
IN PHYSIOGRAPHIC REGION 3
DELAWARE RIVER BASIN

Land Use	Acres	Percent Of Total
Cropland	633,637	36.2
Pasture	59,513	3.4
Woodland	647,641	37.0
Idle	115,525	6.6
Urban	294,064	16.8
Total	1,750,380	100.0

TABLE 22. CLASSES OF LAND ACCORDING TO LAND CAPABILITY
CLASSIFICATION IN PHYSIOGRAPHIC REGION 3
DELAWARE RIVER BASIN

Classes Of Land	Acres	Percent Of Total
I	95,772	5.4
II	488,613	27.9
III	467,344	26.7
IV	24,595	1.5
VI	31,058	1.7
VII	201,539	11.6
VIII	147,249	8.4
Unclassified (Cities, Roads, Water And Other)	294,210	16.8
Total	1,750,380	100.0

Hay And Pasture Land -

The present management of the hay and pasture lands in this physiographic region generally follows the grassland farming type of management. Land used for the production of forage in this region is usually the land that is unsuited for the production of truck or other high value crops. The pasture and hay is allowed to remain for a number of years. The grasses are re-established in a rotation of small grain. Because of the wetness, legumes are subject to severe winter damage and frequently need to be re-established in the stand.

Present management of pastures allows the cattle to graze from early spring to late fall. In addition to resulting in overgrazing, much damage to the soil is done by the trampling of the animals on the wet fields. This reduction in the quality and density of the cover and the compacted soil surface contributes to increases in erosion and run-off.

Several factors have contributed to the heavy use of lime and fertilizers in this region. First, many of the lighter soils are rather low in natural fertility and, therefore, must be fertilized to produce a good crop and, second, the benefits which result from increased applications of fertilizer are well known to the farmers in this area. In the production of truck crops, it is not uncommon for farmers to use from 1,000 to 2,000 pounds per acre applied to a single crop. On the better soils, where rapid leaching is less pronounced, the crops that follow receive benefits from the residue of the previous application in addition to the fertilizer which is applied for their use.

Where high fertility is maintained, the hay and pasture crops together with the small grains and winter cover crops make good growth, resulting in winter protection against erosion and run-off and add large quantities of organic matter to the soil.

Woodland -

The present woodlands of the Coastal Plain region fall broadly into two types -- mixtures of pitch and Virginia pine with generally poor quality oaks on the dry, sandy soils and bottom land hardwoods and pine mixtures on the wet sites.

Generally speaking, forest management in this region is probably the poorest in the Basin. Wild fires are still very common in the dry areas and have reduced much of the timber stand to a nearly worthless scrub cover. A good market exists for sawlogs and pulpwood and the better timber stands are often heavily overcut. This combination of treatment has reduced the productivity of the woodlands to a point far below its potential.

Many of the wetland areas need only drainage to make them adaptable to farming. As a result, on this area of high value land and great demand for farm produce, suitable sites are gradually being drained and converted to truck and other high return crops. It seems probable that this trend will continue and that woodlands will eventually be confined only to the very poorest sites. Even many of these may eventually be cleared for industrial or other urban use.

Idle Land -

The present management of idle land in this physiographic region presents no major problems. The idle land usually consists of areas that are somewhat wet and swampy or good land that has been abandoned for farming and is being held for urban development. Natural vegetation has become established and good hydrologic conditions exist. Further improvement would be difficult in most cases.

Urban -

The management of the urban area in this physiographic region presents a problem similar to that in Physiographic Region 2. In addition, much of the urban development has been on soils where the infiltration rate is high and, under normal conditions, rainfall would enter the soil and contribute to recharging the ground water. However, because much of the water falls on roofs or paved areas, it is put into storm sewers or channelized flow and enters the streams as flood water. This adds to flood peaks and further reduces low flows because of the reduction of ground water. This is of special concern in this physiographic region where salt water intrusion can become a problem.

Effect Of The Going Conservation Program -

Interest in the conservation of soil and water in the Delaware River Basin is high. All but four counties which have a major part of their drainage area in the Delaware River Basin have formed Soil Conservation Districts. These four counties are Sullivan County, New York, and Northampton, Bucks and Delaware Counties in Pennsylvania.

The Soil Conservation Districts have asked for and are receiving technical help from the Soil Conservation Service in planning for soil and water conservation. The Agricultural Conservation Program Service is providing a means of sharing with farmers a part of the cost of carrying out conservation practices. The state foresters are assisting farmers and other property owners with their woodland problems under the acts referred to earlier in this chapter. In addition, there are many other federal, state and local agencies from whom the Soil Conservation Districts can ask and receive assistance.

Some of these agencies include the Agricultural Extension Service,

the Department of Fish and Game, the Highway Departments, the Department of Forests and Waters, and the Farmers' Home Administration. In addition, there are several successful watershed associations in the Delaware River Basin. Some of these include the Brandywine, the Red Clay, the Neshaminy, and the Wissahickon Watershed Associations. Their assistance in reaching the nonagricultural landowner, as well as the farmer, in the interest of conservation has been an important contribution to the development of the conservation programs.

Approximately 5,000 basic farm conservation plans have been prepared by landowners with assistance from the Soil Conservation Districts in the Delaware River Basin. Under these plans, it is estimated that conservation practices have been applied on about 15 percent of the land in the Delaware River Basin. These practices include tree planting, diversion terrace construction, establishment of contour strip cropping, improvement of hay and pastures, waterways and outlets for the safe conduct of water down the slope, farm ponds, woodland improvement and other management practices.

Where these management practices have been concentrated in areas such as a small watershed, the results are significant under certain conditions in the reduction of peak flows. Results indicate important reductions in local floods on the small tributary streams but lesser reductions when storms are of long enough duration to cause floods on main stems.

Although flood damages from local storms are seldom as dramatic, they occur much more frequently and in total probably exceed those from the bigger storms. Thus, the flood reductions from improved land management can make important contributions to the headwater economy.

A more detailed discussion of the effects of conservation measures on the hydrology of the Basin is found in Chapter V.

CHAPTER V

PRESENT HYDROLOGIC CONDITIONS AS AFFECTED BY SOILS AND COVER

SECTION I - INTRODUCTION

1-01. HYDROLOGIC CYCLE

The water supply of the earth is in continual circulation between the atmosphere and the earth's surface. Water leaves the atmosphere in the form of rain, snow, hail, dew, or frost and returns to the atmosphere as water vapor.

Not all precipitation reaches the ground directly; some is evaporated back to the atmosphere during its fall. Some is intercepted by vegetation where it may be evaporated, absorbed by the plants, or eventually reach the ground by flowing down the stems or dripping from the foliage.

Precipitation that reaches the ground may infiltrate into the soil, run off the ground surface, or be evaporated into the atmosphere. Infiltrated water is stored in the earth's mantle as gravitational water, capillary water, or ground water. Gravitational water is stored for a short time in the larger soil pore spaces as it percolates downward through the soil mantle.

On some soils, the lateral movement of gravitational water may be so rapid that it cannot be absorbed by the underlying soil layer. When this happens, the excess gravitational water comes to the ground surface as wet weather springs. When the water-holding capacity of the soil is filled, the excess water is either stored on the surface of the ground or it drains off as "seepage."

Water that doesn't enter the ground may be stored in surface depressions or it may become "surface run-off," flowing along the ground surface until it reaches a stream channel.

Although ground water and gravitational water are subject to transpiration by plant growth, they are not principal sources of transpired water except in wet locations, such as swamps and areas bordering streams and other bodies of water. Capillary water is the principal source of water for transpiration. Evaporation is fed mostly from open water surfaces and capillary water.

The parts of the cycle with which we are concerned in this discussion are those which are affected by the upper layer of the soil mantle and by vegetative cover, since these are the only parts of the cycle which can be

materially affected by land use and management.

SECTION II - THE SOIL-COVER COMPLEX

2-01. PROPERTIES OF THE SOIL THAT AFFECT RUN-OFF

A soil-cover complex is the term used to describe a specific combination of soil and cover for hydrologic purposes. The effect of a particular complex upon run-off will vary with the physical characteristics of its soil and cover.

Due to differences in their physical properties, soils vary in the quantity of water they will hold, in the rate at which water will enter the surface, and in the rate at which water will percolate downward to the water table or laterally to the stream channels. The depth, infiltration at the surface, and structure and texture have profound effects upon the rate and amount of intake and storage of water.

Soil texture is determined by the grain size of the soil particles. This varies from fine clays to coarse sands. Structure is the clumping of soil particles into granules, or soil aggregates, and is dependent upon texture and organic content. Depth, texture and structure of soil determine the amount of pore space available for water storage and movement.

Conditions that provide large pores within the soil mass for rapid infiltration and movement of water and air, combined with small pores for the storage of water, are very desirable. The grouping of individual soil particles into aggregates, which resist the slaking action of water and resist crushing during tillage operations, is an essential feature of good soil structure. Infiltration through the surface is dependent upon texture and structure and governs the rate at which water can enter the soil.

The soils of the watershed have been classified into four hydrologic soil groups. The soils are classified on the basis of rate of intake of water at the end of long-duration storms occurring after prior wetting. This is the rate that is particularly important in the design of structures and other control measures. The relationship that exists between rainfall and run-off on the various soil types under various conditions of cover and management can be predicted within reasonable limits.

Of the four soil groups, Group A is the highly permeable soils. At the other end of the scale, in Group D, are the relatively impermeable soils. The soils in between these groups are Group B (above average intake rates, but below the maximum Group A), and Group C (below average intake rates, but above the minimum Group D). The soil array is based on the premise that bare soils of similar profile characteristics (particularly depth, texture, organic matter content, structure, and degree

of swelling when saturated) will respond in essentially the same manner under a long storm of appreciable intensity.

In the Piedmont (Physiographic Region 2) and Upland (Physiographic Region 1) part of the Basin, typical soils that occur in Hydrologic Group A are Berks shale, Plummer sandy loam and Tunkhannock gravelly loam; in Hydrologic Group B, Dekalb stony loam, Duffield and Lackawanna stony silt loams, and Washington silt loam; in Hydrologic Group C, Culvers and Lordstown stony loams, Oquaga stony silt loam, and Weikert shaly silt loam; and in Hydrologic Group D, Holly, Alvira and Melvin silt loams.

Some typical soils in the Coastal Plain (Physiographic Region 3) in Hydrologic Group A are Evesboro loamy sand, Greenwich loamy sand, and coastal beach and sand dunes; in Hydrologic Group B, Showell sandy loam, Woodstown sandy loam, and Fallsington sandy loam; in Hydrologic Group C, Leon loamy sand, Pocomoke loam, and Portsmouth loam; and in Hydrologic Group D, Keyport silt loam, Leonardtown-Morgenic silt loam, Othello silt loam, and Elkton sandy loam.

2-02. PROPERTIES OF COVER THAT AFFECT RUN-OFF

Vegetative cover is the product of climate, soil, topography and man's desire. Cover for a particular soil determines to a large extent the rate at which water can enter the soil and influences the rate of surface run-off. It influences the depth and distribution of the snow pack, the rate of snow melt, and the loss of water through evaporation and transpiration. It is instrumental in establishing a local climate or a micro-climate which may affect the rate and volume of run-off. Over a long period of time, it assists in the development of soil.

Cover varies widely in density and in type as a result of the activities of man and the variations of climate. Despite the great range in type, all forms of vegetation show certain characteristics that are important in relation to stream flow. All vegetation is made up of three parts: the canopy of living and dead stems and leaves that stand clear of the soil, the accumulation of dead and decaying plant remains that lie on or in the soil profile, and the living and dead roots and sub-surface stems that permeate the soil.

The canopy above ground and the surface litter accumulation operate as barriers interposed between the atmosphere and the soil. They intercept precipitation, insulate the soil, and retard wind movement near the soil surface. Vegetation at the soil surface obstructs the overland flow of water and the pickup and transport of soil material. Beneath the soil surface, to depths reached by roots, vegetation acts both directly and indirectly. Roots, by their growth and subsequent death and decay, permeate the soil with material that both binds it

and aids the flow of water through it. Roots also absorb water and carry it to the above ground parts of plants, thus contributing to the return of water to the atmosphere. Roots may be instrumental in providing avenues for percolation and storage of water in the sub-soil by penetrating below the zone of high organic content and increasing noncapillary porosity.

Vegetative cover and root penetration play a very definite role in the way soils take in water and permit it to move through the soil. The storage of water in the soil, use of this water by plants, and the exchange of gasses between the soil pores and the atmosphere depend to a large degree on how the soil particles are arranged into granules or aggregates. Because decomposing organic matter provides substances that help to cement soil particles into stable aggregates, the return of large amounts of organic residue to the soil usually have a beneficial effect on structure.

2-03. THE EFFECT OF LAND USE ON RUN-OFF

A complex relationship exists between vegetative cover, the use and treatment of the cover, and the soil and run-off. To a large extent, conditions in the upper soil horizon determine whether storm precipitation runs off immediately as overland flow or enters the soil profile and passes off slowly as sub-surface flow. Soil conditions are strongly influenced by the management practices as well as by the type of vegetative cover. It is obvious that, with the numerous types of vegetation and the various kinds of use and treatment occurring on the different hydrologic soil groups, there could be as many as several hundred different soil-cover complexes in the Delaware River Basin.

It is generally recognized that, under most systems of management, land cropped to grass and trees does not present as serious an erosion and run-off problem as land devoted to cultivated crops.

In fact, erosion is practically non-existent on land protected by ample plant cover, regardless of the kind and nature of the cover. Likewise, the loss of water as run-off is directly affected by the plant cover. As plant cover decreases or deteriorates, erosion and run-off losses become progressively higher.

Types of cultivated crops and farming practices likewise affect erosion and run-off losses. The amount or frequency of tillage has a direct relationship upon structure maintenance, which in turn influences infiltration and run-off.

Row crops are more detrimental to soil structure than hay or grass crops because they require many tillage operations, frequently return little organic residue to the soil, and generally have small shallow root systems. In general, the percentage of water-stable aggregates and the

percentage of large pores in the soil are almost always greater after the grasses, legumes, or mixtures of the two, than they are after any other crop.

Perennial mixtures meet most of the requirements for improving and maintaining soil structure. Because the soil is not stirred by tillage implements, aggregates and pores, once developed, tend to persist. The amounts of organic matter returned to the soil through the extensive root systems and top growth, when it is plowed under, are greater for the perennial crops than for most other crops.

In areas where there is a high percentage of urbanization, we have two major factors influencing the amount and rate of run-off: increase of impervious area and a change of travel time.

Impervious areas tend to increase the volume of run-off from a given storm. Those impervious areas cover as much as 15 to 20 percent of the total development areas. Lawns and gardens have infiltration rates approximating that of agricultural land.

In many developments, the peak flow may be affected due to a change in the travel time of the resultant run-off. Care must be exercised in evaluating the effect of peak flow in urban areas. Restrictions, due to inadequate bridge openings, small culverts and undersized storm sewers, may result in back water with resultant reductions in peak flows. Shanklin 1/ has shown that this is actually the case in some New Jersey communities.

The net result is that each urban area must be carefully analyzed to properly assess the net effect on peak flow and on volume.

The types of management and use that are significant in influencing hydrologic conditions are the type of crops (i.e., row, small grain, meadow); the method of farming practices (i.e., straight row, contour row, or terrace row); and for woodland, the timber type and severity of use as indicated by age and density (Table 23).

As indicated in Table 24, the changes in land use and management are reflected in the changes in the soil-cover complex indices for all four soil groups. For example, a row crop without the benefit of contour cultivation under poor hydrologic conditions in Soil Group A has a run-off curve number of 72. This same crop under good hydrologic conditions and cultivated on the contour has a run-off curve number of 65. Water falling on contoured fields during an ordinary rain is detained in the small dams formed by plow, cultivator and drill marks. This retardation of surface water allows further increase in infiltration, thereby reducing surface run-off.

Further examination of these data show that cover management,

1/ Transactions AGU, Vol. 38, No. 3, p. 382, June 1957.

TABLE 23. PRESENT TIMBER CLASSIFICATION BY PROBLEM AREAS DELAWARE RIVER BASIN

Stand Size*, Stocking Density, And Hydrologic Condition**

Problem Area	Total Forest Land	Sawtimber				Poles				Seedling And Sapling		Nonstocked		Problem Area
		Heavy		Light		Heavy		Light						
		Total Area	H.C.C.	Total Area	H.C.C.	Total Area	H.C.C.	Total Area	H.C.C.	Total Area	H.C.C.	Total Area	H.C.C.	
	Acres	Percent	Average	Percent	Average	Percent	Average	Percent	Average	Percent	Average	Percent	Average	Average H.C.C.
1	2,021,706	5	3.6	19	3.3	26	3.3	22	3.0	20	3.0	8	2.7	3.0
2	288,320	6	3.3	30	3.1	19	3.1	12	3.0	14	2.8	19	2.5	2.9
3	363,732	1	3.2	9	3.0	7	3.0	28	2.9	40	2.7	15	2.3	2.7
4	223,636	5	3.3	32	3.1	7	3.1	15	3.0	25	2.9	16	2.4	2.9
5	397,143	10	3.4	24	3.2	11	3.1	12	3.0	16	2.9	27	2.5	2.9
6	694,263	12	3.3	14	3.1	11	3.2	22	3.0	33	2.7	8	2.4	2.9
Total	3,988,800													

* **Timber Stand Size And Stocking Definitions**

Sawtimber - (Trees over 9" D.B.H.)
Heavily Stocked - 5,000+ board feet per acre
Lightly Stocked - 1,500 - 5,000 board feet per acre
Poles - (Trees 5" to 9" D.B.H.)
Heavily Stocked - 600+ cubic feet per acre
Lightly Stocked - 200 - 600 cubic feet per acre
Nonstocked- Not stocked with timber or developed for other purposes

** **Hydrologic Condition Classifications**

H.C.C. - Hydrologic Condition Class
Poor - 2.0 through 2.9
Fair - 3.0 through 3.9
Good - 4.0 through 4.9
Very Good - 5.0 through 5.9

TABLE 24. RUN-OFF CURVE NUMBERS FOR HYDROLOGIC SOIL-COVER COMPLEXES
DELAWARE RIVER BASIN

Land Use And Cover	Treatment Or Practice	Hydrologic Condition	Hydrologic Soil Group A	B	C	D
Row Crops	Straight Row	Poor	72	81	88	91
	Straight Row	Good	67	78	85	89
	Contoured	Poor	70	79	84	88
	Contoured	Good	65	75	82	86
Small Grain	Straight Row	Poor	65	76	84	88
	Straight Row	Good	63	75	83	87
	Contoured	Poor	63	74	82	85
	Contoured	Good	61	73	81	84
Rotation Meadow	Straight Row	Poor	66	77	85	89
	Straight Row	Good	58	72	81	85
	Contoured	Poor	64	75	83	85
	Contoured	Good	55	69	78	83
Pasture Or Range		Poor	68	79	86	89
		Fair	49	69	79	84
		Good	39	61	74	80
Woodland		Poorest	56	75	86	91
		Poor	46	68	78	84
		Medium	36	60	70	76
		Good	26	52	62	69
		Best	15	44	54	61

through the use of small grain and meadows, further reduces the run-off curve number.

The factors that influence the infiltration of storm precipitation into the soil and the reduction of surface run-off on forest lands are, in general, the same as those for other land. These factors are: texture and structure of the underlying soil; degree of protection of the soil against raindrop impact; and density of vegetative cover which intercepts part of the precipitation and, also, through transpiration, depletes soil moisture. The forest builds thick layers of litter and humus which protect the soil surface, improve soil structure, absorb moisture, and impede the flow of water over the soil surface. Under natural conditions, the depth and consistency of the humus and litter layers, the structure of the soil and the density of the crown canopy are all related to the type, age and density of the forest cover.

Any destructive agency that affects any one or all of these interrelated elements tends to decrease the hydrologic efficiency of the land. For example, woodland grazing does not normally destroy the tree cover but it does compress the humus layer, thereby reducing the permeability and absorptive capacity. Trampling by animals compacts the surface of the underlying soil and breaks down its structure.

A ground fire may destroy the humus, burn out the organic matter from the surface soils, and thus destroy structure without destroying tree cover. If the forest cover is also destroyed, then the protective canopy is lost and the process of rebuilding the soil structure and humus layer will take much longer.

Depending upon the local climate, timber type and other factors, destruction of the tree cover by poor logging methods will have a similar effect. If enough of the cover is removed to expose the forest floor to the sun, then the humus will be oxidized just as surely though more slowly than by fire. If the severity of cutting is somewhat less or if the timber type is such that a protective canopy of brush or young trees quickly covers the land, the oxidizing process may be halted while some humus remains.

The forest type, whether it is conifer or hardwood, also influences the kind of humus that will be formed. Each type of humus, in turn, has a different hydrologic efficiency. The type and thickness of humus also strongly influences frost formation in the soil during the winter. Where solid "concrete" frost is prone to form, heavy surface run-off may be expected from winter storms.

Although other factors are also important in determining the hydrologic efficiency of a forest cover, the type and depth of the humus is the most important.

Through a series of studies, the correlation has been determined between the sum of all the forest-use factors in a particular area, as represented by the types and depth of humus and litter, and the relative efficiency of the area to absorb precipitation and reduce surface run-off.

Since humus formation is so closely related to type, age and density of the forest cover by sampling within each stand size class to determine the influences of other factors, it was possible to determine an average humus condition for each type, age and density of stand. With data on location and acreages of stand size and density throughout the Basin supplied by the Forest Service, this average humus condition and the related hydrologic efficiency of the forest could be calculated for any part of the Basin.

2-04. DETERMINATION OF HYDROLOGIC CONDITIONS

Hydrologic condition is defined as the relative ability of a watershed area to retard run-off as compared with its potential under a given cover and use.

For the purpose of the hydrologic classification, the significant cover types are woodland, grassland, cropland, idle land and urban land. Each cover type was analyzed to determine whether a good, fair, or poor hydrologic condition existed. On crop, pasture, idle and urban land, these hydrologic condition classes were developed from existing soil and water inventory data for each state.

Five condition classes have been established for the forested land. They range from poorest (yielding the highest surface run-off) to best (yielding the lowest surface run-off). The hydrologic condition of the forested lands of the Basin was determined by sampling throughout seven counties in three physiographic provinces. Each sample involved measuring forest litter depth, humus depth, and a compaction factor based on the type of humus. A correlation of hydrologic condition and stand size was used to expand the sample information to the entire forested area of the Basin.

2-05. DETERMINATION OF SOIL-COVER COMPLEX INDEX NUMBERS

To establish the relative efficiency to retard run-off between the various soil-cover complexes under specified management practices, a series of curves has been developed to show the relationship between given amounts of precipitation and the corresponding surface run-off for each complex (Fig. 11). This relationship is based upon a thorough review of the thousands of rainfall and run-off records available from small watersheds throughout the country for various soil types and cover conditions.

The derivation of these curves is discussed in the Soil Conservation Service Engineering Handbook on Hydrology, Section 4, Supplement A, Part 3.

SECTION III - PRESENT SOIL-COVER INDICES

An index number, indicating relative efficiency, has been assigned to combinations of cover, condition, management practice, and hydrologic soil group (Table 24).

From field investigations that show cover, hydrologic conditions, management, and soils for a particular watershed area, the proper index number for that area can be determined from Table 24. Using this index number, it is possible to enter the curves and predict the run-off that will result from any given amount of precipitation.

Using the soil group and cover data obtained from the field investigations of the Delaware River Basin, the soil-cover complex indices (run-off curve numbers) were determined and combined into a composite number for each of the six problem areas which make up the total area of the Basin, with the exception of the area in counties with less than 25 percent of their area in the Delaware River Basin (Table 25). Each problem area represents a physical division where geologic, physiographic and climatic conditions are similar. Figure 11 shows the problem areas. To arrive at the composite index for a problem area, the acreages of each soil-cover complex were multiplied by their respective run-off curve numbers. These values were then totaled and divided by the total acreage in the problem area. The same procedure was carried out for each problem area.

This composite index number represents the present hydrologic conditions by problem areas. For a specific watershed within a problem area, a new index number should be developed.

TABLE 25. PRESENT TIME LAND USE ESTIMATE
DELAWARE RIVER BASIN

(1) Prob-lem Area	(2) Hydro-logic Soil Group	(3) Cropland	(4) Cropland	(5) (3) x (4)	(6) Pasture	(7) Pasture	(8) (6) x (7)	(9) Woodland	(10) Woodland	(11) (9) x (10)	(12) Idle	(13) Idle	(14) (12) x (13)	(15) Urban	(16) Urban	(17) (15) x (16)	(18) Wgt. Run-off Curve Number
		Acres	Curve Number		Acres	Curve Number		Acres	Curve Number		Acres	Curve Number		Acres	Curve Number		
1	A	25,655	65.07	1,669,371	11,157	49.00	546,693	43,062	41.00	1,765,542	5,270	68.00	358,360	9,669	84.00	812,196	
	B	162,730	72.55	11,806,062	75,642	69.00	5,219,298	(1,120,252)	64.00	71,696,123	37,279	79.00	2,945,041	24,046	90.00	2,164,140	
	C	102,516	81.58	8,363,255	43,944	75.53	3,319,010	702,94[illegible]	74.00	52,017,703	20,763	85.96	1,784,787	99,158	84.78	8,406,615	69.6
	Total	290,901		21,838,688	130,743		9,085,001	(1,866,256)		125,479,368	63,312		5,088,188	132,873		11,382,951	
2	A	4,034	56.58	228,244	147	49.00	7,203	2,071	42.00	86,982	1,199	68.00	81,532				
	B	169,452	68.84	11,665,076	29,391	69.02	2,028,567	217,642	65.00	14,146,730	46,282	78.42	3,629,434	26,456	84.00	2,222,304	
	C	39,717	77.42	3,074,890	9,929	79.01	784,490	45,974	75.00	3,448,050	16,555	86.00	1,423,730	154	90.58	13,949	70.3
	D	2,176	83.14	180,913	484	84.00	40,656	1,297			665	88.98	59,172	154	92.00	14,168	
	Total	215,379		15,149,123	39,951		2,860,916	266,984		17,631,762	64,701		5,193,868	26,764		2,250,421	
3	A	9,112	61.24	558,019	590	49.00	28,910	5,187	44.00	228,228	1,103	68.00	75,004				
	B	100,680	68.97	6,943,900	5,621	69.00	387,849	101,295	66.00	6,685,470	11,559	79.00	913,161				
	C	90,908	78.57	7,142,642	10,029	79.00	792,291	229,817	76.00	17,466,092	12,038	86.00	1,035,268	27,752	84.00	2,331,168	73.6
	Total	200,700		14,644,561	16,240		1,209,050	336,300		24,379,790	24,700		2,023,433	27,752		2,331,168	
4	A																
	B	153,614	71.34	10,958,823	25,352	69.00	1,749,288	71,594	65.00	4,653,610	13,016	79.00	1,028,264	1,782	84.00	149,688	
	C	143,104	79.46	11,371,044	28,010	79.00	2,212,790	133,754	75.00	10,031,550	9,505	85.69	814,483	40,726	84.00	3,420,984	74.8
	Total	296,718		22,329,867	53,362		3,962,078	205,348		14,685,160	22,521		1,842,747	42,508		3,570,672	
5	A																
	B	305,797	71.87	21,977,630	31,902	69.01	2,201,557	74,454	65.00	4,839,510	30,442	79.00	2,404,918	164,546	84.00	13,821,864	
	C	350,341	79.22	27,754,014	82,992	79.00	6,556,368	287,258	75.00	21,544,350	40,916	86.00	3,518,776	3,264	90.00	293,760	
	D	8,311	83.65	695,215	1,844	84.00	154,896	4,951	81.00	401,031	2,539	89.00	225,971	7,623	8.02	61,136	76.2
	Total	664,449		50,426,859	116,738		8,912,821	366,663		26,784,891	73,897		6,149,665	175,433		14,176,760	
6	A	50,251	65.59	3,295,963	2,622	49.00	128,478	49,219	42.00	2,067,198	22,617	68.00	1,537,956	211	74.00	15,614	
	B	416,021	75.84	31,551,033	40,752	69.00	2,811,888	489,487	65.00	31,816,655	66,268	79.00	5,235,172	5,167	84.00	434,028	
	C	163,953	83.29	13,655,645	15,227	79.00	1,202,933	103,740	75.00	7,780,500	23,374	86.00	2,010,164	289,224	78.07	22,579,718	72.6
	D										1,389	89.00	123,621				
	Total	630,225		48,502,641	58,601		4,143,299	642,446		41,664,353	113,648		8,906,913	294,602		23,029,360	

USE AND MANAGEMENT OF LAND AND COVER RESOURCES OF THE DELAWARE RIVER BASIN

CHAPTER VI

FLOODWATER AND SEDIMENT PROBLEMS

SECTION I - INTRODUCTION

Upstream floodwater problems are of the same kind as found in downstream damage centers. Floodwater damages occurring on individual minor tributaries are small in magnitude relative to those in larger centers of population and industry occupying flood plain lands of the major tributaries and the main stem reaches of the Delaware River. However, the intensity of damages per square mile of drainage area ranges from low to high for both small and large watersheds.

SECTION II - FLOODWATER PROBLEMS

Floodwater damages in watersheds ranging in size from 10 to 25 square miles often attract little attention outside the immediate area. This may lead to a conclusion that such damages are local problems and are of minor importance. To the individuals involved, severe economic losses occur. For the Delaware River Basin as a whole, the sum of such damages represents a serious economic loss.

Frequent flooding occurs in the tributaries throughout the Basin. Some of the more recent floods affecting a number of areas in the Basin occurred in 1933, 1936, 1938, 1942, 1946, 1950, 1952 and 1955. The 1955 storm was the most recent to cause damage over a large part of the Basin. Almost every year, damaging floods occur at some point in the Basin affecting watersheds of 25 square miles or less. These storms are local in nature and cause from moderate to severe damages. For some damage areas, the local storm represents the most damaging of record rather than the large, more or less, Basin-wide storms. Because of this condition, it is difficult to describe floodwater damages in small watersheds of the Basin in terms of one Basin-wide flood event. Data shown in Table 26 list the tributaries known to have experienced floodwater damages. The intensity of flood plain development and use are of sufficient magnitude to classify the flood problems of these tributaries as moderate to high damage potential. Although floods of frequent occurrence do not cause damages comparable to major floods of less frequent occurrence, they do account for a substantial portion of the average annual damages. Frequent floods cause damages to growing crops; land damage from streambank erosion, infertile overwash and scour; damage to minor agricultural improvements, secondary roads and bridges, homes, stores; and create problems in maintaining stream channel capacity.

The problems of a small watershed were studied in detail for

TABLE 26. SMALL HEADWATER STREAMS, WITH DAMAGE REACHES OF MODERATE TO HIGH DAMAGE POTENTIAL
(p. 1 of 2) DELAWARE RIVER BASIN

Sub-basin	Stream	Tributary Of	Major Damage Reach
1	Wright Brook	W. Branch, Delaware	Bloomville
	Steel Brook	W. Branch, Delaware	Delhi
	East Brook	W. Branch, Delaware	Walton
	West Brook	W. Branch, Delaware	Walton
	Oquaga Creek	W. Branch, Delaware	Agricultural land
	Brush Brook	Little Delaware	Bovina Center
2	Bush Kill(upper reaches)	E. Branch, Delaware	Fleischmans
	Downs Brook	E. Branch, Delaware	Downsville
	Cattail Brook	Willowemoc Creek	Livingston Manor
3	N. Branch, Callicoon Creek	Delaware	Hortonville, N. Branch, and Callicoon Center
	E. Branch, Callicoon Creek	Delaware	Jeffersonville
	Panther Rock Brook	E. Branch, Callicoon Creek	Youngsville, and rural area upstream
	Equinunk Creek	Delaware	Equinunk
	Lollipop Creek	Lackawaxen	White Mills
	Laurella Brook	Lackawaxen	Berlin Center
	Carley Brook	Lackawaxen	E. Honesdale
	Middle Creek	Lackawaxen	Hawley, and upstream
	N. Branch, Calkins Creek	Delaware	Millanville
	S. Branch, Calkins Creek	Delaware	Millanville
	Unnamed stream	Neversink	Hugenot
	Saw Kill	Delaware	Milford
	Dwarfs Kill	Delaware	Lower reach
	Mill Brook	Delaware	Lower reach
	E. Branch, Paupack	Wallenpaupack	Greentown
	Wallenpaupack (upper reaches)	Lackawaxen	Newfoundland
4	Bush Kill	Delaware	Bush Kill
	Brodhead Creek	Delaware	Analomink, and E. Stroudsburg
	Spruce Mt. Run	Brodhead	Canadensis
	Rattle Snake Creek	Brodhead	Mountain Home
	Mill Creek	Brodhead	Mountain Home
	Paradise Creek	Brodhead	Paradise Valley
	Pocono Creek	Brodhead	Tannersville
	McMichels Creek	Brodhead	Stroudsburg

TABLE 26. SMALL HEADWATER STREAMS, WITH DAMAGE REACHES OF MODERATE TO HIGH DAMAGE POTENTIAL
(p. 2 of 2) DELAWARE RIVER BASIN

Sub-basin	Stream	Tributary Of	Major Damage Reach
5	Hokendauqua Creek	Lehigh	Petersville and North-ampton
	Bush Kill	Delaware	Above Easton
	E. Branch, Monocacy	Lehigh	Cement plants
	Monocacy	Lehigh	Bath, and part of Bethlehem
	Aquashicola	Lehigh	Palmerton
	Buckwa Creek	Lehigh	Little Gap, and Palmerton
	Mauch Chunk Creek	Lehigh	Jim Thorpe
	Jordan Creek	Lehigh	Upper Reach
6	Little Martins Creek	Delaware	Martins Creek
	Martins Creek	Delaware	Bangor, and Martins Creek
7	Tributary to Tacony Creek	Delaware	Above Ogontz
	Little Neshaminy	Neshaminy	Neshaminy, and Hulme-ville
8	Locust Creek	Little Schuylkill	Tamaqua, and above
	Still Creek	Little Schuylkill	Tamaqua, and above
	Little Schuylkill	Schuylkill River	Tamaqua, and Reynolds
	Koenigs Creek	Little Schuylkill	New Riggold
	Unami Creek	Perkiomen Creek	Finland
	Perkiomen (upper reach)	Schuylkill	Rural homes
	Tulpehocken (upper reach)	Schuylkill	Bernville
	Wissahickon Creek	Schuylkill	Fort Washington
	Stony Creek	Schuylkill	Norristown
9	E. Branch, Brandywine	Christina River	Downingtown
	W. Branch, Brandywine	Christina River	Coatesville
	Sucker Run	W. Branch, Brandywine	Coatesville

Laurella Brook in the preparation of a Public Law 566 watershed work plan for tributaries of the Lackawaxen River, located in Wayne County, Pennsylvania. This watershed has a drainage area of eight square miles. For the August 1955 flood, damages were appraised at $40,000, which would be about $5,000 per square mile of drainage area. The estimated average annual damages from all storms are in excess of $750 per square mile. Frequent flooding occurs on the agricultural land. Less frequent flooding damages rural homes and improvements, roads and bridges. Numerous bridges across the brook are required to provide individual residents access to the highway. The economic loss and inconvenience resulting from damages to these bridges represent the major watershed problem.

The Little Schuylkill River, a larger watershed, was also studied in detail during the preparation of a Public Law 566 work plan. This watershed has a drainage area of 136 square miles. For the flood of August 1955, damages were appraised at $12,000 per square mile of drainage area. Average annual damages for all storms are estimated to be approximately $800 per square mile. Floodwater damage to railroads and industrial plants represented the major monetary loss from the 1955 flood. Residential property, retail stores, roads and bridges, and agricultural property represent the other kinds of property damaged.

SECTION III - SEDIMENT PROBLEMS

Sediment problems in the Delaware River Basin are extremely variable, not only in extent of the problem but also in the types of deposited material. Although generally considered to represent an area of moderate to low sediment concentrations, the average annual sediment load is not disproportionately small when compared to other rivers. Volume II of American Civil Engineering Practice presents a tabulation of data for selected rivers throughout the world. Some familiar rivers show:

Stream	Suspended Load, Tons Per Square Mile
Susquehanna River	38
Potomac River	103
Ohio River Basin average	220
Upper Mississippi, at Quincy, Illinois	68
Missouri River Basin average	325
Danube River, at Budapest	185
Tisza River Basin average	185

An analysis of the records by the U. S. Geological Survey shows a combined average annual load of the Delaware River at Trenton, New Jersey, the Schuylkill River at Manayunk, Pennsylvania, and the Brandywine Creek at Wilmington, Delaware, to be 158 tons per square mile of drainage area.

Data developed for watershed work plans (P. L. 566) on tributaries of

the Lackawaxen, the Little Schuylkill, and Brandywine Creek show an extremely wide variation in sediment sources, sediment quantities and sediment texture.

The Geological Survey has collected fluvial sediment data at selected locations in the Basin since 1947. The Soil Conservation Service has developed data on soil erosion, sediment delivery rates and reservoir sedimentation. A joint report by these two agencies titled "Fluvial Sediment in the Delaware River Basin" is being made as a contribution to the comprehensive survey of the water resources of the Delaware River Basin.

3-01. HEADWATER AREAS

Sediment production rates in the Delaware River Basin have an extremely wide variation, depending upon both the natural watershed characteristics and the use of the land. For example, there is a desilting basin in operation on the Little Schuylkill near South Tamaqua, Pennsylvania, where the contributing drainage area is about 43 square miles. Coal mining activities are prominent in the drainage area. The Department of Forests and Waters of the Commonwealth is required to dredge the basin when it becomes filled to 50 percent of capacity. In the first six years of operation, the basin was dredged four times, yielding 855,000 cubic yards of sediment. Material accumulates in this basin at the rate of approximately 12,000 cubic yards per month. This indicates an annual sediment yield in excess of 2,200 tons per square mile since the basin does not trap all of the load.

This is in contrast to the annual load of Bush Kill at Stroudsburg, Pennsylvania, of 33 tons per square mile. The watersheds are quite similar with the outstanding difference being that the watershed of the Bush Kill is about 90 percent in woodland, while coal stripping and washing plants are dominant features of the Littls Schuylkill area.

Sediment deposits in the steep headwater areas, where the lands are forested, are predominantly coarse materials. These coarse materials have been deposited in large quantities where the flowing waters spread over a wider flow path or where the channels become less steep. Efforts to adapt to the situations produced by the accumulation of these coarse deposits following the hurricane storms of 1955 are still being made. Reclamation of fertile agricultural lands buried by cobbles and sand may never be completely successful, resulting in the abandonment of once highly productive fields and, occasionally, entire farm enterprises. Extensive parts of the highway systems are being rebuilt. In some cases, deposition has been so excessive that the highways must be raised as much as six to ten feet to avoid damages from the very smallest storms.

Sediment yield is also variable in the lower part of the Basin.

The yield of Brandywine Creek, with a predominantly agricultural watershed area, amounts to about 160 tons per square mile per year. Streams such as Chester Creek and Neshaminy Creek, where agriculture in the watershed is giving way to urban developments, have estimated annual sediment loads of about 270 tons per square mile.

The sand and gravel deposits in the headwater areas and the silts and clays in the lower valley and bay are both products of erosion in upstream areas. Ninety-five percent of the sediment in the Delaware Bay passes a 200-mesh sieve. 1/

SECTION IV - EFFECT OF RAINFALL ON SOIL EROSION

Splash erosion is the first effect of a rainstorm upon the land. The falling drops gouge and splatter the exposed soil like many little bombs. This action lifts soil into the air and splashes it back and forth until soil granules have been reduced to soil particles. Soil clinging to foliage or to the foundations of buildings attests to the great quantities of soil moved by raindrop action. Effects of the splashing action can be seen everywhere the land is exposed after any hard rain. The ease with which a given soil is set in motion affects the amount of splash erosion under any set of conditions where raindrops strike bare ground.

Detachability is influenced by the permanent characteristic of the soil type, such as the size and the shape of particles. Most readily dislodged are particles of fine sand. Coarser sands are less easily detached because of the greater size and weight of the particles. Soils of finer texture are less detachable because of the aggregation or cohesion of the particles.

Direct compaction of the soil by the force of the raindrops also occurs. Up to two-thirds of the energy of the falling drops may be used in ramming and compressing the surface.

The effect of these actions is to seal the pores and virtually to waterproof exposed land surfaces during the first few minutes of a rain. In tests with artifically applied rainfall, surface run-off from base plots has started in one to four minutes from the beginning of the application of water. Where compaction is severe, as much as 95 percent of the water applied, even on sandy loams and sands, was lost as surface run-off.

The sealing of the soil surface prevents infiltration and storage of moisture. The excess rainfall that cannot infiltrate accumulates on the surface and provides the surface run-off that carries away the

1/ Schultz, E. A., and Simmons, H. B., Fresh Water - Salt Water Density Currents, A Major Cause Of Siltation In Estuaries, Tech. Bul. No. 2, Committee on Tidal Hydraulics, CofE, U. S. Army, April 1957.

detached materials and contributes to the floods.

The plant cover on the land offers natural resistance to the splash process. To the extent that it intercepts the drops before they strike the soil and absorbs their energy, it reduces the amount of soil detached.

To obstruct the vertical force of the raindrops, the important property of the cover is its density, which provides a complete canopy over the land. That is done by the litter lying on the ground or by standing vegetation, provided it is not tall enough that water dripping from the foliage will have enough impact to cause splash.

Surface run-off water is the second erosive agent of the rain. When rate of rainfall exceeds the intake capacities of the soil, water that is not absorbed where it falls moves across the land as surface flow. It becomes more erosive as it travels downslope.

The amount of soil movement affected by surface flow, like that by the falling drops of water, is a result of the energy of the run-off, the susceptibility of the soil to detachment and transportation by this agent, and the resistance or protection afforded by cover or artificial structures.

Run-off takes the form of sheet flow, or shallow layers of water spread more or less uniformly over the land surface, and channelized flow, which is concentrated into defined watercourses. The distribution of the energy and the resultant type of erosion differ for the two forms. The former, coupled with the raindrop actions, produces sheet erosion. The concentrated scouring action of the channelized flows causes rill and gully erosion.

The energies inherent in the surface flow are greatest on the steepest slopes. Those imparted by the impact of raindrops are uniformly distributed horizontally over the land. It is through the combined action of the raindrops and sheet flow that rainstorms are able to remove fairly uniform layers of soil from large areas (Table 27).

Soil, slope, climate, land cover, land use and management are the prime factors which influence surface run-off and erosion. They vary greatly from watershed to watershed and from drainage basin to drainage basin.

SECTION V - RELATION OF EROSION TO THE SEDIMENT PROBLEM

Erosion is defined as the general process of the wearing away of the earth's surface by natural processes. Sediment yield is defined as the total amount of eroded materials delivered to a given point in

TABLE 27. RELATION OF AMOUNT AND INTENSITY OF RAINFALL TO LOSS OF WATER AND SOIL DELAWARE RIVER BASIN

Number Of Rainfalls	Average Rainfall	Average Maximum Rainfall Intensity 15-Minute Period	Loss Of Soil
	Inches	Inches Per Hour	Pounds Per Acre
	0 1 2	0 1 2 3 4	0 5M 10M 15M
55	0.54	0.50	8
29	0.59	0.62	57
33	0.68	0.77	232
12	0.77	1.14	721
27	0.94	1.50	1,594
9	1.12	2.16	3,527
10	1.73	2.73	5,704
2	1.35	4.00	14,427

Taken from Experiments In The Control Of Soil Erosion In Southern New York, by John Lamb, Jr., J. S. Andrews, and A. F. Gustafson, Bul. 811, Cornell University Agricultural Experiment Station, Ithaca, New York, March 1944.

a natural watershed. Erosion and sediment yield are not synonymous because of progressive deposition of eroded materials enroute from point of origin to the point under consideration in a watershed. However, sediment yield is correlated to an extent with erosion in that a decrease in the supply 1/ (erosion) results in a similar decrease in the yield (sediment).

5-01. TYPES OF EROSION

For simplification in this study, erosion was classified into two general types - sheet erosion and channel erosion. Sheet erosion implies the removal of material from the land surface by prechannel or overland flow; channel erosion occurs as the result of concentrated flow.

5-02. METHODS USED TO ESTIMATE EROSION

a. Sheet Erosion. Materials derived from sheet erosion are inherently fine grained, since prechannel flow, normally laminar, seldom exceeds 2 or 3 feet per second and is capable of transporting only the finer portions of particles detached by raindrop impact. 2/

Analysis of soil loss records for some 40,000 storm events of 20 erosion experiment stations in the United States was reported by Dr. George W. Musgrave. 3/ These studies led to the development of an equation for estimating sheet erosion under variable conditions. The form of the equation used in the Delaware River Basin study was:

$$E = F \times S^{1.35} \times L^{0.35} \times P^{1.75} \times C$$

where E = probable soil loss in tons per acre per year
F = soil factor (relative erodability)
S = slope in percent
L = length of slope in feet
P = rainfall, 2 year frequency, 30 min. max in inches
C = cropping factor

1/ Hudson, H. E.; Brown, Carl; Shaw, Harry B.; and Langwell, J. S., Effect Of Land Use On Reservoir Siltation, Journal of A.W.W.A., Vol. 41, No. 10, October 1940.
2/ Ellison, W. D., Some Effects Of Raindrops And Surface Flow On Soil Erosion And Infiltration, Trans. AGU, Vol. 26, No. 3, pp. 415-429, illus., December 1945.
3/ Musgrave, George W., The Quantitative Evaluation Of Factors In Water Erosion. A First Approximation, Journal of Soil and Water Conservation, Vol. 2, No. 3, pp. 133-138, July 1947.

b. Channel Erosion. Channel erosion implies erosion by concentrated flow. It includes such types of erosion as gully erosion, valley trenching, streambank erosion, streambed degradation and flood plain scour. This type of erosion occurs through the energy exerted by concentrated flow augmented, to some extent, by mass movement and slumping of banks.

Channel erosion, including streambank erosion, wandering stream channels and upland gullies, leaves obvious scars. To measure the growth and extent of these erosion scars, aerial photographs were used as a base. Fortunately, two flights are available for the Delaware River Basin; the early flights were made from 1936 to 1939, and a second flight was made in 1953 or 1954.

5-03. EFFECT OF LAND MANAGEMENT ON SHEET EROSION

Soil loss studies have related sheet erosion to the relative erodability of the soil, the slope, the rainfall and the management of the land. (See methods used to estimate sheet erosion, page 121.) The relative erodability of the soil may be modified by an increase in binding roots and organic matter. Slopes may be modified (shortened) by diversion terraces or other adopted practices. Of all these factors, rainfall alone is not subject to change. The effect of rainfall may be modified by reducing the raindrop impact. These modifications are related to the management of the land.

As may be seen from Table 28, a change from inter-tilled crops to hay results in a substantial reduction in sheet erosion. Contour plowing, strip cropping and diversion terraces influence the effective length of run-off (L) with a corresponding reduction in erosion.

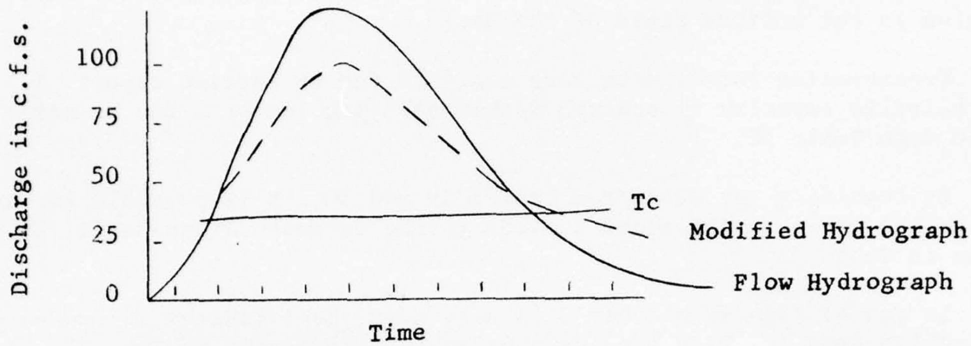
5-04. EFFECT OF FLOW MODIFICATION ON CHANNEL EROSION

Various investigations 1/ have shown that the forces exerted by flowing water are related to (w) the weight of the water, (d) the depth of flow, and (s) the slope. These forces are called "tractive forces." The amount of forces necessary to start erosion of a channel bed is called the "critical tractive force." In any case, erosion starts with some volume of flow and is quantitatively related to the excess forces, that is, the forces above the "critical" value. A typical situation can be illustrated with a sketch. (See page 123)

It can be seen from the sketch that the modification in the peak of the hydrograph would amount to a 25 percent reduction. The modification in the peak excessive force would amount to 33-1/3 percent. The effect on channel erosion would be related to the "time" the excessive forces were permitted to operate. It is interesting to observe that in the operation of reservoirs for flood control purposes with small drainage areas,

1/ Rouse, Hunter, Engineering Hydraulics, John Wiley and Sons, 1949.

it is feasible to control the discharge so that few excessive forces are generated at the outlet. This problem becomes increasingly difficult as the size of the controlled area increases.



The above procedure was used to obtain estimates of the modification in channel erosion in the Delaware River Basin.

TABLE 28. RELATIVE AMOUNT OF EROSION UNDER DIFFERENT VEGETAL COVERS DELAWARE RIVER BASIN

Cropping Practice	Relative Erosion
Forest	.001 - 1.0
Pasture	.01 - 2.0
Hay	0.3 - 3.0
Corn-Oats-Hay-Hay Rotation	13
Corn-Oats-Hay Rotation	22
Continuous Row Crop	100

SECTION VI. RELATIVE EROSION IN VARIOUS PARTS OF THE BASIN

6-01. TYPES OF EROSION

a. Sheet Erosion. Since sheet erosion correlates with the use of the land, Table 29 is indicative of the relative opportunity for sheet erosion in the various areas of the Basin.

Conservation survey data were analyzed for an earlier report. 1/ The relative severity of erosion within each problem area may be estimated from Table 30.

By combining the data from Tables 29 and 30, it is possible to estimate the gross annual sheet erosion in the Delaware River Basin, as shown in Table 31.

It can be seen from Table 31's data that sheet erosion is moderate in Problem Area 1. With the low erosion rate indicated in Table 30 and only 12 percent of the land in cultivation, the opportunity for excessive sheet erosion is not great. Total sediment production in this area is not considered to be materially different than the other areas because channel erosion is so severe and bedload transport is high.

b. Channel Erosion. There are few gullies in the Delaware River Basin. A study of the Brandywine area 2/ shows gullies account for 1.2 percent of the gross erosion. On the basis of reconnaissance surveys and observations, gullies were deemed to be no more severe in the remainder of the watershed. Consequently, gully erosion was considered as a phase of severe sheet erosion in computing sediment sources.

Wandering stream courses and migration of present channels varies appreciably throughout the Delaware River Basin. A detailed study of the Brandywine by the Geological Survey 3/ indicates that streambank erosion is very moderate in this tributary. The watershed study by the Soil Conservation Service indicated that of a gross annual erosion amounting to about 800,000 tons, some 34,000 tons, or 4.3 percent, was from streambank erosion.

In the steep upland stream systems, on the other hand, streambank erosion, bottom land scour and wandering channels are considered to be the principal source of damaging sediments.

1/ Survey Report, Delaware River Watershed, USDA, unpublished.
2/ Community Watershed Work Plan. op.cit.
3/ The Natural Channel of Brandywine Creek, Pennsylvania, Geological Survey, Professional Paper 271, 1955.

TABLE 29. LAND USE
DELAWARE RIVER BASIN

Problem Area		Cropland	Pasture	Woodland	Idle	Urban	Total
1	Acres	290,789	130,756	1,866,256	63,312	132,873	2,483,976
	Percent	12	5	75	3	5	
2	Acres	215,379	39,938	266,984	64,701	26,764	613,766
	Percent	35	6	44	11	4	
3	Acres	200,700	16,240	336,300	24,700	27,552	605,692
	Percent	34	3	54	4	5	
4	Acres	296,718	53,828	205,348	22,513	42,508	620,915
	Percent	47	9	33	4	7	
5	Acres	664,447	116,738	366,663	73,917	175,433	1,397,198
	Percent	48	8	27	5	12	
6	Acres	630,225	58,601	642,446	113,648	294,602	1,739,522
	Percent	36	3	38	7	17	

TABLE 30. EROSION PER ACRE PER YEAR
DELAWARE RIVER BASIN

Problem Area	Cropland	Grassland	Woods
	Tons	Tons	Tons
1	5.7	1.5	0.3
2	20.5	1.9	1.3
3	21.0	1.3	2.5
4	30.7	0.9	1.2
5	22.6	2.4	1.5
6	7.5	0.3	0.1

TABLE 31. ANNUAL GROSS SHEET EROSION
DELAWARE RIVER BASIN

Problem Area	Cropland	Pasture	Woodland	Other	Total
	Tons (000)	Tons (000)	Tons (000)	Tons (000)	Tons (000)
1	1,657	196	560	294	2,707
2	4,415	76	347	174	5,012
3	4,215	21	840	68	5,144
4	9,109	48	246	59	9,462
5	15,016	280	550	706	16,552
6	4,727	17	64	122	4,930

SECTION VII - AGRICULTURAL LAND USE AND PRODUCTION

Flood plain soils are usually more desirable for farming than adjacent upland areas because of topography and fertility. Most of the flood plain area of the Basin has at one time been used for the production of cultivated crops, pasture or hay. Relatively small areas, consisting of narrow bands too small for efficient use, have remained idle or as woodland.

The intensity of use has declined from a relatively large proportion of cultivated crops to pasture, hay crops and idle land. This change in land use can be attributed, in part, to changes in the agricultural economy, but primarily it is the result of inundation, erosion and sediment damage to the land resulting from frequent flooding. The approximate percentage of the area flooded by chance of occurrence in years for some tributaries of the Delaware is:

Stream	Percent Of Flood Plain Area Flooded By Frequency Of Occurrence In Years				
	1 Year	2 Years	5 Years	10 Years	20 Years
W. Branch, Delaware	29	44	57	64	72
E. Branch, Delaware	18	38	53	71	83
Schuylkill River	15	36	61	73	83
Lehigh River	16	34	55	79	87
Tohican Creek	27	58	76	82	88
Brandywine Creek	20	63	80	85	90
Weighted Average	21	44	62	73	81

The above data indicate that annual flooding can be expected to occur on 21 percent of the flood plain and that flooding at 5-year frequencies can be expected to occur on 62 percent of the flood plain.

Present agricultural use of flood plain lands in the Basin, excluding that along the main stem of the Delaware River below Hancock, New York, is as follows: cropland, 35,000 acres; pasture and hay, 72,000 acres; and other uses, 15,000 acres.

Annual crop and pasture damage on the flood plain in most tributary streams is relatively low at the present time since adjustments in land use have been made. Based on sample studies, it is estimated that the present average annual damage to growing crops is $75,000. In addition to this loss, the decline in the intensity of use represents a substantial loss in net income.

Damage to agricultural flood plain land by infertile overwash deposits, swamping, scour and streambank erosion is a watershed problem

associated with flooding. Large flood events frequently cause some damage of this kind to 50 percent or more of the area inundated. Damages to a relatively small percent of the area may be classed as serious because of large drifts of sand and gravel or deep scour channels. Large expenditures per acre are usually required to reclaim these areas for agricultural production. Other areas, less severely damaged by light deposition and slight scour, usually recover in short periods of time with normal farming operations. However, frequent flooding of moderately damaged areas prevents recovery between flood events and results in less intensive use of the area.

SECTION VIII - NONAGRICULTURAL DAMAGES

Flood plains in the headwater areas are used mainly for agriculture. However, the greatest damage potential for monetary loss on these flood plains is associated with homes, retail stores, industry, utilities and parks; in small towns, rural communities and suburban development; also, roads and bridges. The major damages for the streams having moderate to high damage potential, listed in Table 26, are primarily in this type of development and use.

SECTION IX - MORE INTENSIVE USE OF FLOOD PLAIN LAND

9-01. AGRICULTURAL

A change from present idle land to an intensive agricultural use represents a potential benefit if adequate flood protection is provided. The extent of such development is dependent on the capability of the land for more intensive use, width of the flood plain area, the type of agriculture, and the level of protection provided.

The average annual net income that can be expected to accrue from the conversion of idle land to improved hay and cultivated field crops would be about $30 per acre. Enhancement to higher value truck crops would return annual net income ranging from $50 to $100 per acre.

To arrive at a reasonable estimate, of the extent of more intensive agricultural use, would require a detailed study of the present use and expected future development, with specific flood control measures installed. This type of detailed study was not made. However, based on estimated present land use cited above, the potential annual net income from more intensive agricultural use could be in excess of $500,000.

9-02. URBAN DEVELOPMENT

Urban development in parts of the Basin will compete with agricultural use. Flood plain areas of streams like the Perkiomen and Brandywine are of sufficient width and have soils capable of a more intensive agricultural use. Due to the nearness of the flood plain area of these

streams to centers of rapidly increasing population, it is expected that development along these streams may be to uses other than agricultural. The nature, location and timing of such development would require detailed studies of each area.

SECTION X - METHODS USED TO ESTIMATE DAMAGES

10-01. STUDY WATERSHEDS

Damage schedules were prepared for damage reaches below 36 selected structure sites. The length of damage reach studied varied from about 1 to 15 miles. The distance to be studied was determined from a map study and reconnaissance of the downstream potential damage area. The damage study was stopped at the point where the structure would have only a minor effect on reduction of stage. Generally, this was the point where the area controlled by the structure was less than 5 percent of the contributing drainage area.

The flood frequency method was used to make the economic evaluation. From the data obtained in this evaluation, justification criteria were developed for application to other sites in the Basin. This information was supplemented by data from Public Law 566 watershed work plans which had been previously prepared for watersheds in the Basin.

Annual damage factors were computed for different kinds of property, such as homes, retail stores and agricultural land. The method used is further explained by the following with respect to damage rates for houses. A study was made of 73 houses located in several watersheds in the Basin to determine average annual floodwater damages. Average annual damages for these houses were computed by the frequency series method of establishing a stage-damage and damage frequency relationship. The market value of each house, subject to floodwater damage, was appraised. The average annual floodwater damage determined for each house was divided by the market value to determine average annual percent damage factors.

These houses were classified as to magnitude of damage potential as low, moderate or high. The computed mean annual percent damage was .5 percent for the low group, 1.0 percent for the moderate group and 2.0 percent for the high group.

The houses classified as low damage potential represent those on the higher elevation of the flood zone and receive infrequent lawn and basement damage. The moderate damage class represents the houses located at lower elevation in the flood zone and are subject to more frequent lawn and basement flooding and moderate damage from first floor flooding during major floods. The high damage class represents houses in the lowest elevation of the flood zone. Smaller, more

frequent floods cause damage to lawns and flooding of basements. The large floods cause severe damages due to greater depth of flooding on the first floor.

It is recognized that property elevation in the flood zone in relation to streambank elevation as well as hydrologic characteristics of the stream must be considered in the classification of each property as to magnitude of flood damage potential. The following items were considered in the classification of each property in the flood zone of damage reaches evaluated by this method: (1) Size of drainage area above the damage reach, (2) capacity of stream channel, (3) width of flood plain, (4) secondary information and interviews concerning the history of flooding and extent of floodwater damages, and (5) elevation of property with respect to streambank elevation.

10-02. FIELD STUDY OF DAMAGE AREAS

From a map study, 127 sites were believed to warrant at least a field reconnaissance. A field reconnaissance was made of the damage reaches below each of the 127 potential structure sites. Data were recorded for each reach showing the number and value of houses, number and size of retail stores, kind and size of bridges, and agricultural acres and use. A limited number of local residents were interviewed to determine the history of flood damages and outline the approximate limit of the flood zone. The elevation of property in the flood zone with respect to streambank elevation was estimated.

10-03. APPLICATION OF AVERAGE ANNUAL DAMAGE FACTORS

Appropriate factors were applied to kinds of damages by damage reaches to obtain the estimated average annual direct damages. Time would not permit the location and inclusion of all improvements in low intensity use areas and, since business losses were not included, the direct annual damages were increased by 20 percent. This is believed to represent a conservative estimate of the unevaluated damages. Indirect damages were estimated to be from 15 to 25 percent of direct damages.

SECTION XI - SEDIMENT DELIVERY RATES

11-01. SEDIMENT YIELD

Sediment yield is defined as the total sediment outflow from a watershed. It includes both bed materials and suspended materials. Sediment yield is a function of the amount of erosion in the watershed and the efficiency of the stream systems to transport the eroded materials. The term "delivery rate" expresses the relationship of the amount of erosion to the amount of sediment yield. Delivery rate is expressed as a percentage of the gross erosion.

11-02. DELIVERY RATES

Delivery rates depend upon many factors. It is obvious that the transport efficiency of a steep watershed will be appreciably higher than that of a flat area. Since it is generally true that the slope of a watershed increases as the size decreases, the delivery rate in small watersheds is usually high, gradually decreasing as the watershed size increases until it becomes a relatively small fraction of the gross erosion on watersheds exceeding 100 square miles in size.

Gross erosion in the Brandywine Watershed is estimated to be approximately 805,500 tons per year. 1/

The sediment yield is defined at one place in the Brandywine Watershed by the measured load at Wilmington. An analysis of the record indicated an average of 50,898 tons per year in suspension at Wilmington. The bed material load has not been measured. Increasing the measured load by 20 percent (to account for unmeasured suspended load and the bed load) indicates an average sediment yield of about 62,000 tons per year. This would define the delivery rate as being about 8 percent of the gross erosion.

Studies by Louis M. Glymph and others show that the delivery rate varies inversely as the two-tenths power of the drainage area for large watersheds. 2/ Based on the measured data at Wilmington, it is possible to develop a delivery rate curve for the Delaware River watershed. This curve is reproduced in the companion report by the U. S. Geological Survey and the Soil Conservation Service titled, "Fluvial Sediment in the Delaware River Basin" (Fig. 12).

Since these data are based on measurements of suspended load and reservoir deposits, they are presented as "order of magnitude" estimates which account for those types of sediment only. The data do not reflect the problems associated with bed material sediments which, as previously explained, are generally deposited in the steep headwater areas or above the crest of reservoir impoundments.

By combining the data in Tables 29 and 30 and applying the factor for delivery rate determined from the curve, the following tabulation of sediment production, by tributaries, was developed (Table 32). This tabulation is intended to indicate the magnitude of the sediment production from various tributaries. The variation in this estimate from the true sediment yield may be appreciable where the land use within the particular watershed is at significant variance with the average land use within the general problem area. For example, average area of cultivated land in Problem Area 5 amounts

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1/ A Community Work Plan For The Brandywine, USDA, SCS.

2/ Presented in a paper at the International Association of Hydrology, Rome, Italy, 1954.

to 48 percent. The percentage of land in cultivation in the Brandywine Watershed is about 32 percent. Adjusting for this difference only, the quantity shown for the Brandywine on Table 32 varies from the estimated yield, based on the suspended load record by 6.5 percent. In the Nashaminy Creek watershed, the suspended load measurements indicate a sediment yield of 270 tons per square mile per year; whereas, the estimate based on land use data indicates a yield of 176 tons, a difference of 35 percent. The Nashaminy Creek area is undergoing extensive urbanization. Such changes in land use will be reflected in significant changes in sediment yield.

TABLE 32. SEDIMENT YIELD RATES FOR PRINCIPAL TRIBUTARIES
DELAWARE RIVER BASIN

Tributary	Drainage Area	Cover			Sheet Erosion	Delivery Rate	Average Annual Sediment Yield
		Crop	Grass	Woods			
	Square Mile	Percent			Tons/Square Mile	Percent	Tons/Square Mile
E. Branch, Delaware	840	12	14	74	877	4.4	39
W. Branch, Delaware	664	12	14	74	877	4.8	42
Equinunk Creek	58	12	14	74	877	11.2	98
Lackawaxen River	601	24	46	30	1,490	5.0	74
Mongaup River	202	2	8	90	441	7.5	33
Neversink River	346	2	8	90	441	6.2	27
Bush Kill (Stroudsburg)	156	2	8	90	441	8.2	36
Brodhead Creek	287	12	14	74	877	6.6	58
Paulins Kill	177	35	21	44	2,010	7.8	157
Pequest River	158	35	21	44	2,010	8.1	163
Lehigh River	1,364	31	18	51	2,210	4.0	88
Musconetcong River	158	31	36	33	1,812	8.1	147
Assunpink Creek	91	36	26	38	605	9.7	59
Neshaminy Creek	233	48	25	27	2,484	7.1	176
Rancocas Creek	342	36	26	38	605	6.2	38
Perkiomen Creek 1/	362	25	45	30	1,620	6.0	97
Schuylkill River	1,909	44	19	37	2,650	3.0	80
Chester Creek	66	48	25	27	2,480	10.7	265
Brandywine Creek 2/	329	48	25	27	2,480	6.4	159
Christina River	568				1,720	5.1	88
Salem River	112	36	26	38	605	9.0	54

1/ Tributary to Schuylkill River.
2/ Tributary to Christina River.

CHAPTER VII

FUTURE MANAGEMENT AND USE OF SOIL AND COVER

SECTION I - INTRODUCTION

The previous chapters of this report have discussed the management, use and present conditions of soil and cover in the Delaware River Basin. This chapter deals largely with trends in management and use, projections and assumptions that will affect the hydrologic conditions of the watershed.

In estimating the effects of future management and use of land and cover on the Basin's hydrology, two points must be considered: first, the amount of land that will be converted to uses that decrease infiltration and increase run-off, such as rooftops and pavements; and second, the type of management on the land remaining in both natural and cultivated vegetative cover.

Those management practices which increase soil storage of precipitation, either by improving structure or by adding to the overlying mat of organic material, tend to help regulate streamflow. The result is a reduction in the amount of overland flow, with a consequent reduction in the rate of movement to channels and a decrease in the supply of sediment to the stream system. One of the major limiting factors governing the effectiveness and applicability of these practices is the physical characteristics of the soil to which they will be applied.

The regimen of a stream is constantly changing. Since geology and topography are relatively fixed characteristics, it follows, then, that under normal conditions, the variations in run-off which occur from a drainage basin are the reflections of variations in the weather and changing uses being made of the land.

SECTION II - TRENDS IN LAND USE

2-01. CONVERSIONS TO NONAGRICULTURAL USES

In Chapter III, it was shown that there is a persistent decrease in the amount of land available for agriculture.

A study of the total area of two counties, more than half of another, and the expansion areas of six satellite cities in the Basin provides the basis for projecting future growth patterns, assuming relatively free choice of land quality by investors and builders.

Productive cropland was most intensively converted for urban and industrial purposes in all areas studied. The proportions of total land used that came from cropland ranged from a low of 72 percent in New Castle County, Delaware, to nearly all in the Dover, Delaware, and Bridgeton, New Jersey, areas. The proportions of pasture converted, generally, were about twice as large as from woods; practically no woods had been converted to urban use in some areas.

As a result of this survey, the following proportions for future land transfers to nonagricultural uses based on projected population growth were developed: from present cropland, 75 percent; from pasture, 15 percent; and from woods, 10 percent (Table 33).

Variations from these and other estimates or assumptions made in this survey must be recognized in any attempt to arrive at the drain from cropland within individual counties. For example, in the Wilmington service area (New Castle County, Delaware, and Salem County, New Jersey), it is apparent that New Castle County is well advanced in urbanization and that Salem County still is largely rural. Present land use patterns differ, and it follows that future urbanization will draw on the several land use categories in different degrees between the counties.

a. Urbanization. Present and future competition for agricultural lands in the Delaware River Basin is significant to any study of water management adjustments being made in the Delaware River watershed. Details on probable use of these land resources and indicated competition for them must be known before any basis exists for analysis of demands for water or relative use values of land, or water between farming and urban or industrially-generated uses.

The exact amount of farm land within the Basin taken from active agricultural use by urban-industrial expansion in recent years is not known. Neither is there adequate information about the nature of this land. As urban communities continue to expand, more agricultural lands will disappear. As technology affects production per acre as well as costs of production, other shifts will occur in uses of land.

Unpublished data from the Soil Conservation Service indicate that 200,000 acres of cultivable land have been converted to nonfarm uses in the entire States of Delaware and New Jersey in the fifteen years since 1942. New York and Pennsylvania each have lost nearly 1,000,000 acres during the same period.

The United States Census of Agriculture shows that 4,000 farms, totaling over 202,000 acres, disappeared between 1939 and 1954 in the nine-county Philadelphia metropolitan area. Cropland harvested dropped 44,673 acres during this period.

Study of aerial photos of Burlington County, New Jersey, to compare

TABLE 33. NONAGRICULTURAL REQUIREMENTS FROM RURAL LANDS
DELAWARE RIVER SERVICE AREA

Area	Population				Land Area Required		
Sub-regions [1/]	Actual [2/]		Projections [2/]				
	1955	1965	1980	2010	1965	1980	2010
	(000)	(000)	(000)	(000)	Acres [3/]	Acres [3/]	Acres [3/]
New York City Metropolitan	13,851	16,000	18,500	25,000	578,081	672,500	1,748,500
New York City Supplement	1,221	1,500	2,000	3,400	75,051	134,500	376,600
Bethlehem-Allentown-Reading	798	900	1,100	1,550	27,438	53,800	121,050
Trenton Metropolitan	250	300	400	650	13,450	26,900	67,250
Philadelphia Metropolitan	4,121	4,800	5,800	7,900	182,651	269,000	564,900
Wilmington Metropolitan	329	450	600	1,000	32,549	40,350	107,600
Upper Basin	551	650	750	950	26,631	26,900	53,800
Southern Basin and Coastal	469	600	850	1,300	35,239	67,250	121,050
Total	21,590	25,200	30,000	41,750	971,090	1,291,200	3,160,750

1/ The groupings of counties in the Delaware Service Area, by the Office of Business Economics, accounts for the larger acreage in land area required than that applicable to the Delaware Basin proper.
2/ Economic Base Survey of the Delaware River Service Area, Office of Business Economics, U. S. Department of Commerce.
3/ The average per capita factor, developed by Agricultural Research Service, U. S. Department of Agriculture, for all urban uses of land for new population is estimated to be .269.

land uses in 1956 with those of 1940, was made for the upper 46 percent of the county. This sector included most of the agricultural land uses and precluded most of the state-owned forest and brush lands, recreational developments and military reservations.

During the 16-year period -- and largely in a much shorter time -- 13 percent of the rural land had changed to nonfarm uses or was in process of change. Using the 1940 cropland acreage as a base, 23 percent no longer was in active agriculture; 12 percent of the pasture, 5 percent of the woods and 3 percent of the idle cropland had passed to urban and industrial uses or was seriously encroached. Cropland provided 74 percent of the area for urban and industrial growth, pasture provided 13 percent, and the remainder came from wooded areas.

Of the above former cropland, 38 percent had become urban, 7 percent was in new roads and highways, 39 percent was idle, and 16 percent was in transition to urban uses or closely encroached by urban uses. Sixty-five percent of this cropland had been of good, irrigable quality; 19 percent was of fair quality; and 16 percent was of poor quality due to poor drainage, slope, or other reasons.

When all of the land whose former use had changed is considered, 61 percent had been on soils suitable for irrigation; 18 percent would have been fairly suitable; and 21 percent was poor, usually due to drainage conditions.

The riverfront of Burlington County, New Jersey, has had industry and urbanization for some time. Growth largely was oriented to bridges crossing the Delaware River. No direct, through rail connections between New York, Philadelphia, Baltimore, and Washington intersect the county. Development of truck transportation, together with the Delaware Memorial Bridge and the New Jersey Turnpike, opened north central Burlington County to expansion of industry. Good terrain for construction, availability of large tracts of relatively low cost land, and improved location situation have encouraged growth of some light industries in this area. Greater interest has been shown in residential and service-type construction.

The bulk of the good agricultural land in Burlington County lies in the vicinity of the turnpike and river crossings. Speculation in land values, an uncertain future, and excellent opportunities for work in nonfarm jobs have brought about changes in land use in the county. The Census of 1954 shows considerable decline in numbers of farms, acreage in farms, and cropland harvested within most of the northern townships.

Adjacent to the turnpike in central Burlington County, the area, including the townships of Lumberton, Hainesport, Mount Holly, Mount Laurel, Evesham, and Springfield (mostly SCS Resource Area 2A), apparently has felt little effect of urban demands for land. Numbers of farms declined only 4 percent, land in farms declined only 1 percent, but cropland

harvested declined 17 percent. An increase in idle cropland accounted for some of the decline in harvested acreage, but much of the difference resulted from nonfarm developments. The number of persons commuting from this section to urban jobs has increased.

It is generally believed that residential areas, service areas and even light industry will develop near interchange points on limited access highways. This has not been borne out at present in Burlington County from study of the aerial photos or from observations made on the ground in 1957. The upper half of the county certainly is in line to participate actively in future urban-industrial growth of the Philadelphia metropolitan area. This idea is borne out by Parsons, Brinckerhoff, Hall and MacDonald (consulting engineers) in their report "Southern New Jersey Mass Transportation Survey" (1956). They indicate rather dense land settlement for the northern portions of the county, stringers along the main arteries leading to the coast, and cells of concentration near main intersections as the probable pattern.

Losses of agricultural land are not occurring uniformly. Urban and industrial developments are hitting hardest at the rich truck crop and intensive dairying sections. However, large segments of low grade cropland have been retired from use as uneconomic producers under modern methods. Other tracts are held idle for a variety of reasons.

Evidence from impact studies in other areas outside the Delaware River Basin indicates that the effects of urbanization extend far beyond the tracts actually used. Land values are affected by generated high nonagricultural demand. Normal agriculture is more easily superseded by urbanization than is an agricultural community already in transition. Commercial farm enterprises respond to changes in costs and are displaced relatively quickly under unfavorable economic conditions. Part-time farmers or others who are in phases of transition respond less quickly to economic changes in agriculture because economics is secondary in importance to speculative interests and circumstances peculiar to the situation.

b. Recreation. The extensive land-using types of recreation which customarily are confined to rural areas are of two general types: one, those lying within 50-60 miles of sizeable cities; and two, more remote areas. The nearby parks, picnic areas, playgrounds, golf courses, outdoor movies, race tracks, etc., are used intensively and usually are developed following heavy pressures from nearby population centers. These uses require large areas of level, well-drained land. Interspersed rougher and wet areas often can be utilized for other recreational uses.

The projected population growth in the Philadelphia metropolitan

area, together with current unmatched needs for recreational areas, undoubtedly will result in development of many additional intensively used recreational areas by 1975, with still more units added between 1975 and 2010. The time is rapidly passing when lands suitable for such purposes will be available. Such lands already are high-priced, due to the demand for areas for residential housing development.

There seems little question that under future conditions in the Delaware River Basin, a large portion of the remaining forest land will yield the most direct benefit to the greatest number of people for recreational areas, with watershed protection an important complementary benefit. Because of probable demand for mass recreational areas, it is expected that a considerable percentage of such lands may eventually pass into public ownership for park, mass recreation, and hunting and fishing purposes. However, these uses usually do not normally make significant detrimental changes in the forest cover, and it is expected that under proper management these lands will continue their effectiveness in the control of erosion and the regulation of waterflows.

c. Roads. Increasing populations, more leisure time, and a population increasingly dependent upon safe, rapid transportation require that more and more land area be utilized for interstate, intercity and local roads and highways. In this study, no data on future requirements other than the federal interstate highway program (1957-1970) are available. State and county governments normally plan their construction programs for only one or two years in advance since their funds come from annual or biannual appropriations. No attempt is being made to develop these data for the Delaware River Basin.

Considerable area will be required for new roads in the future, but firm bases for determining the amount of land required for this purpose are not available. The problem was resolved by adding 10 acres per 1,000 persons for roads to the acreage of parks and playgrounds and assuming the same distribution in source of land.

Road and highway construction has traditionally tended to follow the valleys both because costs are lower and because these are usually the most direct routes connecting centers of population. This trend is expected to continue in the future and, therefore, a very small percentage of present woodland area will be converted to these uses.

SECTION III - CONVERSIONS BETWEEN EXTENSIVE AND INTENSIVE AGRICULTURAL USES

It is anticipated that as the intensity of land management increases and as pressures develop which will encourage maximum production from each acre of agricultural land, conversions in use will take place to more nearly use land according to its productive capability. At present, there is a large acreage (1,024,240 acres) of Class I, II and III land still remaining in woodland. There are many reasons for this present use. Some

areas are in small tracts surrounded by larger areas of poor quality lands, some are now too far from markets to be economically operated, a considerable acreage is held in estates and other ownerships not interested in farming, and still others for a variety of reasons. It has been assumed that under future conditions a high proportion of existing woodland in these classes will be converted to more intensive use.

Another considerable acreage of land in Class VI, VII and VIII is now being used for crop and pasture land or is standing idle. Under future conditions, these lands will tend to become uneconomic for farm operation and, if they are to stay in any form of agricultural production, will probably be converted to woodland.

The net result of these conversions will be to reduce the woodland area by about 750,000 acres throughout the Basin. Of this amount, however, about 300,000 acres, or over one-third of the total, will take place in the Coastal Plain region, where the effect on the Basin hydrology will be insignificant.

None of the statistics for Bucks County, Pennsylvania, will support the premise that agriculture tends to change toward enterprises which use land more intensively in a zone immediately beyond the fringe of urban growth. The 1954 Census enumeration may have been too early to record shifts which now have taken place, but it is more likely that the ownership pattern is not slanted toward maximization of agricultural production. Production of truck crops in Bucks County has declined sharply. Most of the soils adapted to production of these crops lie in lower Bucks County, which has borne the brunt of urbanization. Much of the central area is rolling and has soils developed on Piedmont topography not well adapted to modern truck cropping practices. Other nearby areas have competitive advantages for the available truck crop markets. Remaining Bucks County farmers have better alternative opportunities. The major exception is a temporary situation along the banks of the river where the land is held for gravel production and used temporarily for truck crops.

Farm size is more stable in Bucks County than in some other areas further afield. Adjustments in acreage to utilize modern innovations are difficult. Land values are high due to speculative pressures and few farms become available for division among adjacent farm operators. Farm operators, on the other hand, are working too near the limits of their present labor, capital and equipment to take on relatively large additional tracts of land. Many dairy farmers are limited in possible adjustments by the size of their barns and their ability to house and handle additional livestock.

Hence, we find intensification occurring on dairy farms as represented by increased production per cow and maintenance of corn and

soybean acreages. Although Census data do not bear out the assumption, the acreage of hay and cropland pasture probably has been maintained and production of feed units per acre increased on these farms contrary to the county-wide trend downward.

Sheep and beef enterprises would be something out of keeping if Bucks County were a "typical" agricultural county. However, many of its old farms were purchased for rural estates by nonfarmers and are devoted to such uses. These enterprises can utilize the available roughage to advantage and even will pay for fertilizing and improving the pastures. They require less labor and attention than dairying and have certain aesthetic values for their owners. Such flocks and herds often provide additional income and amenities as prize winning breeding herds.

The foreseeable future for Bucks County seems to require that agricultural land uses continue to be extensive, with probably greater dependence on grasslands than today. Under a logical program of planned land utilization, dairying, beef and sheep would retreat in orderly fashion before the growth of urbanization. Truck crop production will largely disappear, except in favored patches where small market garden operators or part-time farmers produce for roadside stands or sale at the farm.

Nursery stock and greenhouse production will increase significantly as an agricultural enterprise, but the acreage involved will not be great.

The remaining truck crops, nursery stock and greenhouse operations by 1975 probably will be in the magnitude of 500 to 600 acres under present assumptions of population growth. This acreage probably would shrink to 200 or 300 acres by the year 2010 and remain at about that minimum level thereafter. All of this acreage would be managed intensively, including use of irrigation.

As in Bucks County, Pennsylvania, the farmers of New Castle County, Delaware, are adjusting to urban opportunities and to changing times. The operators of small farms are finding better alternatives in industry; the efficient farmers are becoming more efficient.

Another adjustment already under way is the shift from dairying to truck farming in the Middletown, Delaware, area. Early potatoes are followed by a late cole crop - broccoli, cabbage or cauliflower.

Present trends in land use indicate that by 1975, in the State of Delaware there will be relatively little farmland left north of the Chesapeake-Delaware Canal. Dairying probably will decline from present levels in New Castle County. Potatoes and vegetable production, together with increased cash grains, already is moving into the concentrated dairying area around Middletown, as was noted earlier. The new center of milk production probably will move westward toward or beyond the Delaware-Maryland line.

The studies indicate that similar conversions will occur over the entire Basin. In the areas near the New York-Trenton-Philadelphia-Wilmington metropolis, the conversions are likely to be toward more intensive uses of land suitable for the production of high value crops. This will result in pushing the general farming and dairying into areas of rougher topography and onto soils less suited to vegetables and other high valued crops.

Studies and projections of probable trends in future urban and industrial expansion in the Delaware River Basin indicate that a relatively small percentage of the present woodland area will be affected. As might be expected, it is anticipated that the greatest proportion of this conversion will occur in the small scattered woodlots now surrounding major population centers. These estimates show that the present woodland acreage in Physiographic Region 1 will be further reduced by approximately 50,000 acres; Physiographic Region 2, 150,000 acres; and Physiographic Region 3, 50,000 acres.

These percentages and acreages seem small in comparison with those expected to be taken from cultivated lands, but all indications show that urban and industrial development avoids the more difficult and more expensive building sites that are usual in most of the remaining woodland areas.

SECTION IV - TRENDS IN MANAGEMENT

As was discussed in Chapter IV, improved land management is an important part of the program of the Soil Conservation Districts. Landowners, both farmers and nonfarmers, are planning and installing practices that will tend to prevent further deterioration of the soil and increase its productivity. At the same time, this improves conditions favorable to the reduction of run-off and erosion. These practices include improved crop rotations, improved pasture management, contour cultivation, strip cropping, retiring critical areas, terracing, tree planting, fire control, and other conservation measures necessary for the protection and improvement of the land. It is expected that, as farming adjustments are made to technological changes and as increased production becomes more desirable because of increased demands for farm products, the trend toward better land management will accelerate and expand.

The discussion in Chapter IV indicated the important role that the type of ownership plays in arousing interest in good land management. A very unusual situation exists in the Delaware River Basin due to the large amount of forest land that is held for recreational purposes. Studies by the National Park Service, the Office of Business Economics, and by many quasi-public and private agencies indicate that this trend in ownership by people who own forest land for recreation and resort uses will increase markedly in the future as personal

incomes, leisure time and population numbers increase.

In spite of the trend in ownership, there has been a slow but steady improvement in forest protection and management evidenced over the past few years. This improvement probably results, in a large part, from public and private forest management assistance programs and is expected to continue into the future as these programs become even more effective.

In addition, over the past few years, there have been very significant increases in stumpage values, particularly on high quality logs of preferred species. There is reason to believe that these values will be maintained in the future. Well managed, high yielding forests in the Delaware River Basin, because of their relative proximity to markets and the resulting freight advantage, can provide a very satisfactory annual income. The present outlook is that these opportunities for economic returns will become even more attractive in the future.

The principal management problem for the future is that of creating markets for the large volume of low value hardwoods, which must be removed to convert the present stands into thrifty forests that will have the greatest influence on watershed conditions.

Solution of this problem will depend primarily on the establishment of industries that can utilize small sized and low grade hardwood material. To further complicate the problem, industries such as these have many requirements beyond the mere availability of raw material. They also require the presence of an adequate labor force, adequate transportation facilities, a power supply, markets for their products that can be reached under freight rates at least competitive with those for other areas, and usually, and sometimes most important, an adequate water supply. The inhabitants of the area must also be receptive to the establishment of such an industry within their communities.

The establishment of a pulp mill, somewhere within the Basin, would be of great assistance in solving this problem since such a mill can make good use of large quantities of low grade material. A recent study in Pennsylvania shows that the requirements for the establishment of an integrated pulp and paper operation could be reasonably well met in northern Pike County. The greatest drawback to this location, from the industry's point of view, is that any effluent from the mill discharged into the Delaware River would require complete waste disposal treatment. Under present conditions and regulations, there are other competitive sites in the state that would require much less expensive waste treatment. However, this situation may change as the "clean streams" program progresses and more restrictive requirements are established for other areas. A pulp mill with a capacity of 100 tons per day would use from 100 to 300 cords of wood per day, depending upon the wood species and the pulping process used. The mill would also require between 5 and 15 MGD of water, depending upon the pulping process. However, very little

of this water is consumed and most of it would be returned to the stream for re-use after treatment.

Other smaller industries, such as charcoal production, chemical distillation, and chip and particle board production, can also make good use of low grade material. Their site requirements are not as strict as those for a pulp mill, but neither do they use wood in nearly as great quantities. However, if a number of such industries could be established throughout the Basin at a sufficient distance from a major pulp mill location so as not to be competitive for raw material, they would greatly aid in the solution of the problem.

A corollary problem accompanies the establishment of such wood using industries. There is a great temptation to overcut the immature stands closest to the mill or to cut sawtimber-size trees which yield a greater volume of wood per dollar of harvesting cost. If such indiscriminate cutting were to take place, it would further deplete the present timber stands and aggravate the present problem. Some means would need to be devised to prevent this kind of exploitation.

SECTION V - NEEDED CHANGES IN THE DIRECTION OF USE AND MANAGEMENT

Agriculture should be encouraged to continue where soils and climate are favorable, suitable markets are available, and where urbanization can expand relatively easily onto less productive lands. In some cases, premature speculative land market activity forces agriculture out of production before urban needs actually develop.

Residential development, and to some extent industrialization, should be encouraged to utilize lands less well adapted to agricultural purposes. Highways need not always usurp lands along the valley floor. Urban services and urban developments should be encouraged only in complete units which upset economic conditions of distinctly farming communities as little as possible. Farmers should not be taxed for urban services they do not need and cannot use. More planned development is needed.

Several important interrelated forest land uses will be of increasing importance in the future. These include recreation, hunting and fishing, the production of forest products, and watershed protection. Under multiple-use management, the simultaneous realization of a high proportion of all of these values is feasible. In a few minor watersheds, where conditions are unusually critical, special methods of management may be needed. However, in most of the Basin, the thrifty, productive forests that will yield the highest economic returns will also give adequate watershed protection. By careful planning and management, timber can be harvested from most of the land and the aesthetic background and other conditions necessary for recreational use can be maintained. Timber harvest can be

managed to improve the habitat for wild game and fish and create greater opportunities for hunting and fishing.

However, with a decreased acreage and greatly increased use, these future forested lands will need intensive management if they are to make their potential contribution to the economic and social welfare of the Basin's future population.

In reviewing the land and water requirements today and taking into consideration the estimated land and water requirements of the future, it is essential that steps should be taken to conserve and efficiently use and manage agricultural resources. Recent population trends indicate that most of the new citizens will become urbanites. This will intensify the problems of water supply facilities and developments.

The following management changes are suggested:

1. Land use planning and zoning legislation to preserve good agricultural land for agriculture and to direct urban and industrial uses to other sites.

It has become apparent that the preservation of the best agricultural land is crucial in many places. For example, the State of California has passed a state law that prevents the annexation of zoned agricultural land by cities, unless owners of farmlands give their consent. In almost every case where Class I soils occur, a growing urban center is spreading out from the center of the area. These towns originally were located as urban service centers for agricultural communities. With increasing population pressure, these towns have now spread out over their most fertile acres, destroying the very asset that brought them into being. Agricultural zoning, if widely adopted, promises far-reaching benefits to all people. It is a significant step toward soil conservation and land use and management.

2. Watershed management be applied that will make the most effective use of water on the land and in channels upstream, to deliver downstream the maximum quantity of usable water each year, and to provide facilities downstream for effective control of water delivered there.

3. If necessary to achieve watershed management objectives, critical portions of watersheds be placed in public ownership and the cost of watershed measures on private land necessary to the public interest and beyond those necessary to achieve the primary purpose of ownership be paid for by the benefiting group.

Essential reservoir sites for water supply, stream flow regulation, and flood control should be acquired as soon as possible or otherwise protected. Flood plains subject to frequent flooding should be zoned or acquired for appropriate public uses.

4. That urban, industrial and highway development provide adequate compensatory measures to control sediment and run-off from these areas.

The Nassau County Department of Public Works, Long Island, New York, has installed a number of diffusion basins for funneling run-off from highways, urban areas and other impervious surfaces to the underground storage. The amount of water added to the aquifers in this manner is reported to equal 40 million gallons per day. Additional diffusion basins are contemplated. Most of the diffusion basins are presently located in central Nassau County, an area which shows especially high diffusion rates into gravels and coarse sands. Diffusion basins of this type would be appropriate for the Coastal Plain areas of the Basin.

SECTION VI - RESULTS EXPECTED FROM CHANGES IN USE AND MANAGEMENT

The results of assumed changes in land use and improved management reflects the expected improvement in the hydrologic conditions of the Basin.

Data have been prepared for each of the problem areas for the time intervals 1975, 2010 and 2060, respectively. From these data the change in low flows, peak flows, and annual yields have been calculated.

Comparing the present conditions to conditions which are expected to exist in 2060, results in an increase of 6 percent in low flows in the upper part of the Basin or Problem Area 1. The percentage of increase reduces slightly from problem area to problem area, moving downward toward the mouth of the river. The percent of increase is 4.6 percent for Problem Area 2; 3.7 percent for Problem Area 3; 3.5 percent for Problem Area 4; 2.6 percent for Problem Area 5, and 2 percent for Problem Area 6.

The expected changes in use and improved management show a resulting decrease in peak flows for the year 2060, as follows: Problem Area 1, 8 percent; Problem Area 2, 6.2 percent; Problem Area 3, 5.2 percent; Problem Area 4, 4.9 percent; Problem Area 5, 3.6 percent; and Problem Area 6, 2.8 percent.

The reduction in annual yield, due to the changes in use and improved management for the year 2060, is very slight. This varies from a reduction of 1.5 percent in Problem Area 1 to .5 percent in Problem Area 6. The other four problem areas fall in between these two and are as follows: Problem Area 2, 1.20 percent; Problem Area 3, 1 percent; Problem Area 4, .9 percent; and Problem Area 5, .7 percent.

Although these percentages are relatively small, when they are applied to their respective areas they represent significant quantities in relation to low and peak flows. However, the decrease in annual yield is insignificant.

USE AND MANAGEMENT OF LAND AND COVER RESOURCES OF THE DELAWARE RIVER BASIN

CHAPTER VIII

NEED FOR UPSTREAM STRUCTURAL MEASURES

SECTION I - INTRODUCTION

Damages from floodwater and sediment in the tributaries of the Delaware River Basin, upstream from the proposed principal watercourse projects, attain significant proportions. There is need for water storage in the headwater areas for municipal water supply, rural use, irrigation and recreation. Floodwater and sediment damages are discussed in Chapter VI.

In order to meet the needs of the area for conservation of the land resources, for regulation of streamflow, alleviation of floodwater and sediment damages, and to provide water storage for beneficial use, the land treatment measures (as discussed in Chapter VII) will need to be supplemented with structural measures. This chapter will discuss structures needed for conservation of the watershed lands, flood prevention and agricultural water management.

SECTION II - MEASURES FOR WATERSHED PROTECTION

2-01. LAND TREATMENT MEASURES

In developing plans for watershed protection and flood prevention, land treatment measures are the nucleus or initial increment. Structural measures are included to the extent that they can be justified by the benefits that could not be achieved by the application of needed treatment measures.

Measures, such as terracing; waterway improvement; and skid road and trail stabilization, installed to supplement and complement the vegetative measures, are considered as land treatment measures for flood prevention.

As pointed out in Chapter VII, the amount of land that will be converted to uses that decrease infiltration and increase run-off, such as urban area and highways, and the increased pressure on the agricultural and forest lands, both for vegetative production and for recreation, will necessitate careful management of all the lands in the Basin if floodwater and sediment problems are to be kept within reasonable bounds.

Water disposal systems, terraces, diversions, the stabilization of skid roads and trails, and construction of stock water facilities are

among the important practices which landowners and managers can now install with assistance from various sources.

2-02. STRUCTURAL MEASURES

a. Floodwater Retarding Structures. The objective for construction of floodwater retarding structures is to reduce the stage and frequency of flooding on downstream improvements and agricultural land. This type of measure may be used independently or in combination with other measures, such as channel improvement and diking.

Floodwater retarding structures are most effective when located immediately above a damage center. In addition to protection from loss of life, a major objective in the location of a structure is to achieve a satisfactory level of protection of lands and improvements within the damage reach to be protected. Complete protection of all property is not normally economically feasible. The desirable level of protection varies with different kinds of property and the depth of flooding likely to occur. The level of protection is best described as the expected reduction in flood stage and damages for a given frequency storm event. Projects primarily for agricultural benefits are usually planned so that the remaining risks of flood damages to agricultural lands will not be a deterrent to the fullest utilization of these lands within their soil capabilities. Projects planned primarily to protect urban areas must provide for keeping water out of the major part of the urban areas from floods at least equal to the largest floods of record. In some cases, protection should be even greater. In all cases requiring federal participation, benefits must exceed the cost of the project before authorization is requested.

(1) Present Needs - Type and Magnitude of Damages. As indicated in Chapter VI, there are extensive damage areas upstream from the proposed principal watercourse projects. There is substantial interest in the upstream area, as evidenced by the applications submitted by local organizations for assistance in watershed planning under provisions of the Watershed Protection and Flood Prevention Act (Public Law 566).

A list of the Public Law 566 projects may be found in Chapter IX.

A work plan prepared by the local organization, with assistance from the Department of Agriculture for the Little Schuylkill River watershed, under authority of Public Law 566, is an example of the situation existing in these upstream areas. The August 18, 1955, flood in one evaluation reach of Tamaqua caused damages of $169,000 to business, streets and bridges, homes, and the railroad. Three retarding structures, controlling 79 percent of the drainage area when installed, will reduce the stage for a similar event to prevent all except very minor damages. In a lower reach of Tamaqua, with 15 additional square miles of uncontrolled

drainage area, the three structures provide 55 percent control of the drainage area. Damages in this reach in 1955 were estimated at $540,000, compared to expected $30,000 damages had the structures been installed. For the entire watershed, damages estimated for the August 1955 flood of $1,662,000 would have been reduced to $119,000, with the entire program of land treatment, retarding structures, and channel improvement installed.

The Pennsylvania Department of Forests and Waters has numerous projects within the Basin. On a number of projects, the Department of Forests and Waters and the Department of Agriculture have cooperated in the formulating of plans for channel improvement and floodwater retarding and multi-purpose structures. In many places, these programs complement and supplement each other.

Examples of this are contained in the watershed work plans for Brandywine Creek and the Lackawaxen River tributaries.

In the former, two structures include storage for fish and wildlife purposes, and two include storage for municipal water supply. These added features were developed in cooperation with the Pennsylvania Department of Forests and Waters and the Pennsylvania Fish Commission. In the Lackawaxen, the Public Law 566 reservoir project complements the channel improvement project which is to be developed by the Department of Forests and Waters.

A compilation of data developed for watershed work plans and the comprehensive survey, as described in Chapter VI, indicate that the estimated average annual damages for those watersheds within the Basin considered to have a potential for floodwater retarding structures are estimated to be in excess of $1,800,000. (See Table 34) The estimated average annual damages by kinds of property are: agricultural, $70,000; commercial, $720,000; residential, $300,000; roads, bridges and railroads, $700,000; and sediment and flood plain erosion, $50,000. In addition to these, there are many streams on which the concentration of the damages is not sufficient to justify the installation of floodwater retarding structures. No monetary evaluation of these damages was made. Neither was any estimate made of damages to wildlife or other recreational values.

Figure 13 shows the location and classification of damage areas within the Delaware River Basin. These have been sub-divided to show those areas where preliminary examination indicates that floodwater retarding structures are physically and economically feasible, and also those areas where these measures do not appear to be feasible under present conditions.

The following description of conditions and needs in the Delaware River Basin by sub-basins is based upon a general type of

TABLE 34. WATERSHEDS WITH PRESENT DAMAGE POTENTIAL TO INDICATE JUSTIFICATION OF STRUCTURAL MEASURES DELAWARE RIVER BASIN

Sub-basin	Watershed	Tributary Of	Estimated Average Annual Damages					
			Agri-cultural	Commer-cial	Residen-tial	Road, Bridge, Railroad	Sediment And Erosion	Total
			Dollars	Dollars	Dollars	Dollars	Dollars	Dollars
1	East Brook	W. Branch, Delaware	7,160	7,859	13,500	4,384		32,903
	West Brook	W. Branch, Delaware	5,860	6,431	600	15,587		28,478
2	None							
3	N. Branch, Calicoon Creek	Delaware	400	7,180	8,480	23,160	2,960	42,180
	Lackawaxen Tributaries	Lackawaxen	4,603	6,311	4,245	12,831	2,171	30,161
	Wallenpaupack	Lackawaxen	19,860	61,267	49,694	50,204	6,955	187,980
4	Brodhead Creek	Delaware	11,865	97,203	29,663	317,621		456,352
	Pocono Creek	Brodhead Creek	6,404	22,139	11,710	142,711		182,964
	Paulins Kill	Delaware		11,000	8,367			19,367
5	E. Branch, Monocacy	Lehigh	4,205	44,568	2,448	14,796	1,175	67,192
	Aquashicola	Lehigh	5,000	36,873	40,783	16,891	5,000	104,547
	Mauch Chunk Creek	Lehigh		25,000	13,300	2,000		40,300
6	Little Martins Creek	Delaware	140	17,500	3,933	1,025		22,598
	Bush Kill (upper reaches)	Delaware	1,280	69,262		15,060	1,158	86,760
7	Tributary of Tacony Creek	Delaware			6,200			6,200
	Little Neshaminy	Neshaminy	5,068	28,099	64,775	10,548	840	109,330
8	Little Schuylkill	Schuylkill		61,453	9,600	48,799		119,852
	Wissahickon Creek	Schuylkill		11,305	7,840	15,824	4,000	38,969
	Stony Creek	Schuylkill		21,000				21,000
9	Brandywine Creek	Christiana River		184,348	21,687	10,844	25,080	241,959
	Total		71,845	718,798	296,825	702,285	49,339	1,839,092

preliminary study and data obtained from the 1950 Survey Report for the Delaware River Basin by the Department of Agriculture. Exceptions to this are studies of those watersheds on which detailed studies have been made for watershed work plans completed under authority of Public Law 566. These are listed in Chapter IX, Table 44.

(a) Sub-basins 1 and 2 - West Branch and East Branch. The topography of these sub-basins is mountainous on the western slope of the Catskill Mountains. The streams are steep, with deep narrow valleys. Due to the narrow valleys, the extent of agricultural land in the flood plain is relatively small and represents a minor need for flood protection.

Homes and roads built along many of the small streams have experienced floodwater damages. Average annual damages along East Brook and West Brook in Sub-basin 1 were estimated to be in excess of $60,000. No damage centers were found in Sub-basin 2 with sufficient annual damages to justify retarding structures.

(b) Sub-basin 3 - Hancock-Port Jervis. The topography of this sub-basin is characterized by the Pocono Mountains. Streams are high gradient with narrow flood plains. Recreation is important in the area, with many summer homes and resorts built along the streams. Water-flow control measures apparently are feasible on the North Branch of Callicoon Creek, Lackawaxen tributaries, and Wallenpaupack. Estimated average annual damages on these streams are $260,000.

(c) Sub-basin 4 - Port Jervis-Belvedere. The topography ranges from low mountains to hills with moderately steep slopes. Recreation is also important in this sub-basin and many homes, resorts and roads have suffered severe damages along the streams of this area. The need for protection of agricultural land is significant in the southern part of the sub-basin. The Pequest River, pilot watershed protection project, has been completed to provide protection to agricultural land.

Streams on which protection is needed include the Brodhead Creek, Pocono Creek, and Paulins Kill. Estimated average annual damages on these streams are in excess of $650,000.

(d) Sub-basin 5 - Lehigh. This sub-basin is primarily made up of the Appalachian Valley and Ridge section and the low mountain area of limestone soils. Both agricultural land and urban areas need protection along the streams that are tributaries to the Lehigh River. However, the intensity of development and use of the flood plains along these streams do not represent a high potential at the present time for justification of flood control measures. The following streams have damages of sufficient magnitude to indicate that structural measures appear physically and economically feasible: East Branch of Monocacy, and Mauch Chunk Creek. The estimated average annual damages along these

streams are in excess of $200,000.

(e) Sub-basin 6 - Belvedere-Trenton. This area is in the Piedmont section, with rolling topography of low hills and streams having moderate gradient. The areas in need of protection are dispersed and at the present, structural measures appear to be feasible only for Bush Kill and Little Martins Creek, with estimated average annual damages in excess of $100,000.

(f) Sub-basin 7 - Trenton-Philadelphia. This sub-basin lies mostly in the Coastal Plain section. Topography is slightly rolling to flat, with low gradient streams. Water storage sites are limited. This area has a rapidly expanding population. Many homes, business, and industry have received floodwater damages along some of the streams.

Potential sites for water storage are occupied by extensive improvements. The estimated average annual damages along the Little Neshaminy and a tributary of Tacony Creek are in excess of $115,000.

(g) Sub-basin 8 - Schuylkill River. The Schuylkill River rises in the Appalachian Valley and Ridge section and flows through the Ridge and Valley area of Berks County, Pennsylvania, and gently undulating to rolling topography of the Triassic Basin of sandstone and shale and the Piedmont Plateau area. Tributary streams to the Schuylkill range from high gradient with narrow valleys to moderate gradient with medium width valleys.

Floodwater damages to urban areas, roads and agriculture have occurred frequently on a number of streams. Floodwater retarding structures are needed on the Little Schuylkill and its tributaries, Stony Creek, and the Wissahickon Creek. The estimated average annual damages along these streams are in excess of $175,000.

(h) Sub-basin 9 - Philadelphia-Bay. This sub-basin is mostly in the Coastal Plain physiographic region, with a small part in the Piedmont Plateau problem area. Development and use of the flood plain for homes, industry and business are increasing and the present need for protection, which is already significant. can be expected to increase. The estimated average annual damages along the Brandywine are in excess of $240,000.

(2) Future Needs

(a) Floodwater Retarding Structures. Population growth and expansion of urbanization and industry in the Philadelphia metropolitan area, Reading, and Wilmington will exert pressure for future development of flood plain areas and the water resources. The size of

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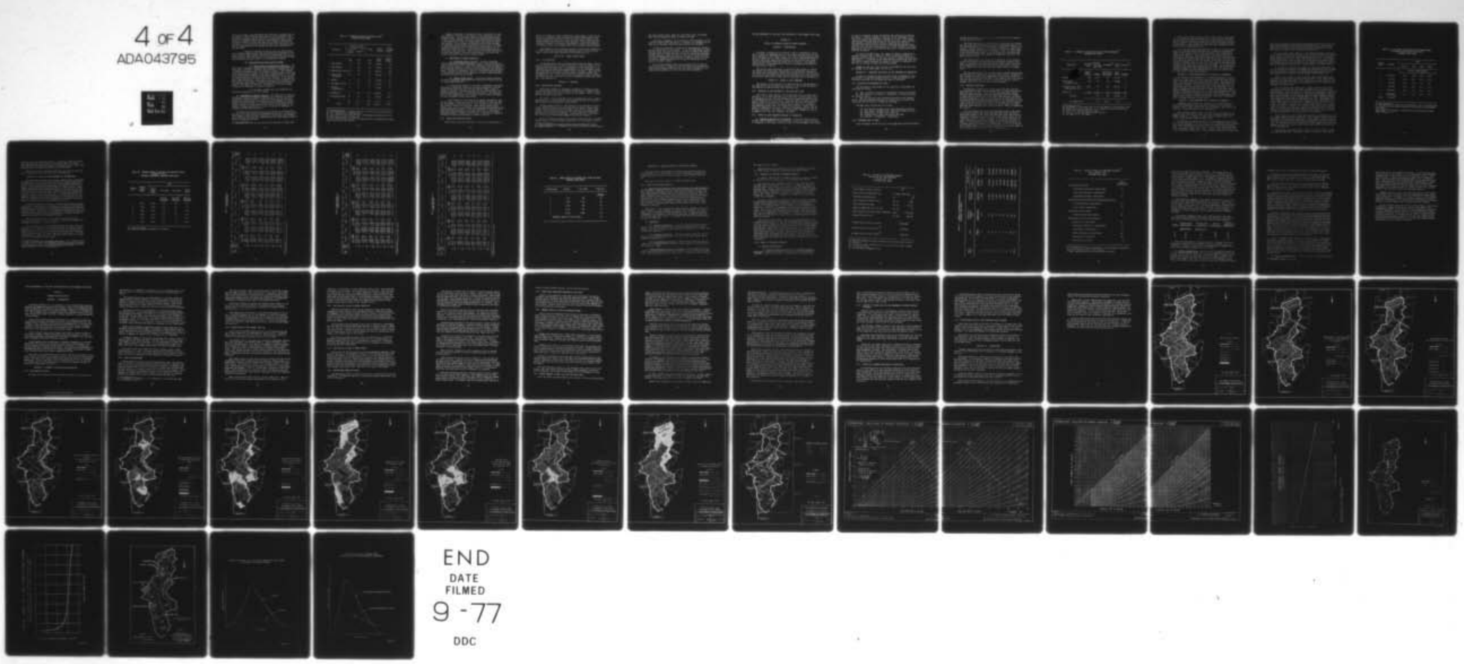

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flood plain areas in the Brandywine and Perkiomen is suitable for development to a more intensive agricultural use with adequate flood protection. However, present ownership intentions are not in the direction of developing these lands to a more intensive agriculture; therefore, benefits of this type were not considered for future development. It can reasonably be expected that this land will be subject to strong pressure for suburban and industrial development by the year 1980.

Sites are available and may be used for flood prevention or multi-purpose storage when development has progressed to the point of need. Under present conditions of development, the use of these sites for the installation of flood prevention and water management structures does not appear to be economically feasible.

(b) Water Supply and Multi-Purpose Storage

(1) Water Supply, Recreation and Other Uses. The study made of tributary streams by the Department of Agriculture for this report indicated a potential water storage of 528,000 acre-feet in addition to present needs for floodwater storage. This information, along with the location, individual storage potential, and other pertinent data was furnished to the Public Health Service, U. S. Fish and Wildlife Service, and the National Park Service. It is expected that these agencies will analyze the data in relation to the over-all water needs of the Basin. The need for and use of the potential sites for municipal water supply, fisheries and recreation will be determined by the respective agencies. The number of sites and storage potential, by sub-basins, is shown in Table 35.

(2) The water storage needs for irrigation are discussed in Section III of this chapter.

b. Improvement of Channel Capacity. The objectives of this measure are to reduce the damages resulting from inundation of valuable bottomlands; provide outlets for drainage works; and furnish flood protection for high value improvements, such as highways, railroads, bridges and farm buildings. To accomplish these objectives, the discharge capacity of stream channels will need to be increased by the removal of debris and sediment deposits, clearing and snagging, realignment and bank stabilization.

An example of the need of this type of measure is illustrated by the plan 1/ to widen and realign approximately two miles of the Paulins Kill channel in the vicinity of Blairstown, New Jersey. The average annual benefit resulting from installation of the improvement at Blairstown is estimated at $12,034.

1/ Watershed Work Plan for the Paulins Kill watershed, October 1958

TABLE 35. POTENTIAL AUXILIARY RESERVOIR SITES 1/
DELAWARE RIVER BASIN

	Sub-basin	Reservoir Sites: Flood Control 2/	Reservoir Sites: Others 3/	Total	Total Storage	Total Drainage Area
		No.	No.	No.	Acre-Feet	Square Miles
1	West Branch	3	39	42	70,096	155
2	East Branch	0	24	24	36,193	116
3	Hancock-Port Jervis	14	58	72	150,122	459
4	Port Jervis-Belvedere	31	20	51	60,704	203
5	Lehigh	2	16	18	52,320	133
6	Belvedere-Trenton	2	9	11	37,223	92
7	Trenton-Philadelphia	4	5	9	12,515	47
8	Schuylkill	9	52	61	148,593	418
9	Philadelphia-Bay	10	21	31	45,505	147
10		0	0	0		
	Total	75	244	319	613,271	1,770

1/ Limiting criteria - minimum capacity of 4 inches of run-off and minimum of 1 square mile of drainage area.
2/ Sites justified for flood control, some having possibilities for additional water storage for other use.
3/ Sites which may be justified for agricultural or nonagricultural water supply other than flood control.

Channel improvement is deemed necessary or desirable at literally hundreds of points in the channel of the tributaries of the Delaware River. The 1950 Survey Report by the Department of Agriculture for the Delaware River Basin recommended the installation of an estimated 423 miles of stream channel improvement on tributary streams. This estimate was developed from a reconnaissance of selected tributary reaches throughout the watershed. It should be understood that critical stream reaches may or may not be contiguous and that 400 miles of stream channel improvement may involve over 1,000 locations. Much of this work has been constructed by individual farmers, local and state agencies, railroads, and stream improvement associations (fishing clubs).

c. Improvement of Channel Stability

(1) Streambank Erosion Control. Eroding streambanks cause sedimentation damage downstream; loss of flood plain land adjacent to the eroding bank; and menace highways, bridge abutments and other riparian property. Control of eroding banks can be attained by sloping the banks and protecting them by mechanical and vegetative means. Fencing of streambanks, except at protected watering places, is an important measure if the banks are to remain stabilized where livestock has access to the stream.

(2) Channel Stabilization. Stabilizing channel gradients to prevent aggrading, deepening or bed erosion will require the use of stabilizing structures.

An appreciable amount of the channel improvement now deemed necessary is intimately related to excessive quantities of bed material being transported into critical reaches (such as under a bridge or trestle). An alternate proposal, the stabilizing of the upstream degrading reach, is frequently overlooked. The stabilization of these degrading reaches (sediment source areas) may require the use of gradient control structures.

The increase of flow capacity by channel improvement, such as the removal of snags and bars or the smoothing of bends and channel realignment, invariably results in an increase in the power of the stream to erode the stream bed. Where natural grade control (ledge, rock, etc.) is not present, the resulting bed degradation may work progressively upstream. This bed degradation in turn may be a hazard to bridge abutments, may expose pipe lines, or accelerate streambank erosion. Channel stabilization is, therefore, frequently interrelated with the improvement of channel capacity.

2-03. DEBRIS AND DESILTING BASINS

Debris basins and desilting basins involve the construction of

basins to impound or retard flowing water long enough to induce the deposition of sediment. Debris basins are usually constructed to trap coarse sediment and debris at or near the point where a high velocity stream emerges onto an area of lesser gradient. Desilting basins are intended to detain flowing water long enough to induce the deposition of sediment carried in suspension, while also trapping coarse sediment.

The Schuylkill River restoration project involved the construction of three river desilting basins and making repairs to seven existing dams to perform the added functions of desilting basins. 1/

SECTION III - WATER STORAGE NEEDS

3-01. FOR IRRIGATION

A study was made of the irrigation needs within the Basin. The results of this study may be found in Appendix G, entitled "Water For Irrigation And Rural Water Use." As pointed out in that appendix, it is estimated that irrigation water requirements for the foreseeable future may be provided by developing present sources of supply. These include the development of springs, on-farm storage, tributary streams, and groundwater (wells). In the event water from these sources is preempted for other uses, the supply will need to be augmented by additional storage. (See Appendix R)

SECTION IV - DRAINAGE

4-01. AGRICULTURAL DRAINAGE

There was no attempt to determine the amount or location of agricultural drainage needs for the purpose of this survey. However, incident to the studies for other portions of this chapter, areas of poorly-drained land were delineated.

The extent of poorly-drained soils is comparatively small in Physiographic Region 1, which comprises the northern one-third of the Basin. Well-drained soils predominate in this region.

In Physiographic Region 2, the majority of the wetlands are found in the Piedmont Plateau section and the Triassic Basin. Those in the former consist principally of wet weather seeps on lower slopes along streams. In the Triassic Basin, the wet soils range from moderately well-drained to very poorly-drained. In other portions of this Basin, the soils tend to become water-logged during the wet seasons.

By far the greatest amount of wet soils in the Basin occur in Physiographic Region 3, including about 30,000 acres of tidal marsh. Within

1/ Water Resources Investigations Relating To The Schuylkill River Restoration Project, p. 9, Department of Forests and Waters, Harrisburg, Pa.

the inner Coastal Plain, there are significant areas of wetlands which can be improved by means of surface drainage.

Individual landowners are carrying out land drainage to a considerable extent within the Basin. In general, the drainage can be done on an individual farm basis where outlets are available.

In the wet upland soils, diversions or drainage-type terraces may be used as well as tile drains. In the wet bottomlands, methods employed range from land leveling to systems of bedding for surface drainage and tile drains and open ditches for sub-surface drainage. In many instances, lands are kept in a wet condition by periodical flooding or aggradation and plugging of channels. Where this problem exists, channel improvement or diking and pumping may be required to provide relief.

Much of the wetlands might attain greater value if used for wildlife purposes. Programs for the development or improvement of these areas as habitat for wildlife can best be developed by coordination with federal and state fish and wildlife agencies.

USE AND MANAGEMENT OF LAND AND COVER RESOURCES OF THE DELAWARE RIVER BASIN

CHAPTER IX

EFFECT OF UPSTREAM MEASURES ON WATER RESOURCES

SECTION I - INTRODUCTION

The Corps of Engineers was directed to make a comprehensive survey and to prepare an integrated plan for the control and utilization of the water resources of the Delaware River. The task of formulating this plan was to be shared by all state, interstate, muncipal and federal agencies having a direct and long-standing interest in the problems and in any plans for development which may emerge from the survey. (See Chapter I, "Agriculture in the Delaware Basin," Part A, "Introductory Perspective for Agriculture," page 2)

The United States Department of Agriculture has agreed to estimate the present and future water requirements for agricultural purposes in the survey area, determine how these needs may best be met, and determine the effect of land treatment and structural measures for flood prevention and watershed protection on high and low streamflows and on sedimentation.

SECTION II - EFFECT OF LAND TREATMENT

The purpose of this section is to show how the use and management of the land affects the distribution or pattern of run-off and the quality and quantity of water available for beneficial use.

2-01. RELATION OF LAND TREATMENT TO THE HYDROLOGIC CYCLE

The place of land treatment in the hydrologic cycle is discussed in Chapter V. It is shown that the use of land, type of crops grown, and the management of open land and woodland have a measurable effect on the run-off characteristic of the area. Since the effect of these land management practices is related to the ability of the soils to respond to the practices, a series of soil-cover complex indices was developed. (See Hydrology Guide, USDA, Soil Conservation Service) Indices were assigned to combinations of cover, condition, management practices and hydrologic soil group. (See Table 24, in Chapter V) Changes in cover or management will result in a change in the index.

2-02. EFFECT OF LAND TREATMENT MEASURES ON STREAMFLOW

a. Computing The Effect on Streamflow. Soil-cover complex indices provide a facile method of relating changes in land use, cover conditions, or management to hydrologic conditions, and are used throughout this report.

A study of streamflow records corroborates the estimates developed by the indices. Without a change in land use, better management of the cover will improve the hydrologic condition of an area. For example, computations resulting from the use of the soil-cover indices indicate that changing a representative 100-acre area from poor rotation, straight row cropping to good rotation, contoured cropping may reduce peak flow from the area by 14 percent, for a 6 inch rainfall in 24 hours. Changing the same area to good pasture may result in reducing the peak flows by 31 percent.

In larger watershed areas, this degree of change is generally impossible to attain and, in addition, these results may be wholly or partially offset by shifts in land use, such as the shifts entailed by urbanization. In addition to the urbanized area, farmers may clear hillside land or convert woodland or pasture to cropland to compensate for the loss of cropland to urban and suburban growth.

Changes in land use, cover condition, or management are reflected by a change in the index number for the area.

SECTION III - MEASURING THE EFFECT OF LAND TREATMENT ON STREAMFLOW

In order to corroborate the calculated effect of vegetative cover improvement on hydrologic characteristics in large watersheds, an investigation was made on five gaged watersheds in the Basin.

3-01. SELECTION OF WATERSHEDS FOR STUDY

The requirements established for the selection of watersheds for study were as follows:

a. That a minimum of 40 years of streamflow records be available

b. That there be no diversion or regulation of streamflow during the period of record

c. That the trend in cover conditions be known on the drainage. areas. (In each watershed selected, the trend in cover condition was improving over the period of streamflow recording.)

The gage areas selected were as follows:

(1) West Branch, Delaware River, above Hale Eddy, New York
(2) East Branch, Delaware River, above Fish's Eddy, New York
(3) Beaver Kill, at Cook's Fall, New York
(4) Delaware River, above Port Jervis, New York
(5) Bush Kill, at Shoemaker, Pennsylvania

3-02. PROCEDURE USED IN STUDY

Total discharge records for each of the gaged areas and precipitation

records for stations in and near the study watersheds were compiled for each year of record.

The first part of the study consisted of treating total streamflow and total precipitation by years, in a double-mass analysis, to see if any change in the trend (increase or decrease in flow) was occurring. For each watershed, the resulting double mass curves indicated that annual flow has been consistent in time. In other words, in the study watersheds where cover conditions have been improving with time, no statistically significant change has occurred in the annual volume of flow.

The second part of the study was to determine if any increase in base flow could be detected from the streamflow records of the areas. A review of the streamflow records revealed that the period July through October was the season of low flow and most likely to be the period of the year when base flow would sustain the streamflow.

The low season flow, July through October, and the precipitation for the same period and for an antecedent period, April through June, were compiled for each of the gaged areas for each year of record. Since in this test period flows were to be compared with other periods from the same watershed, the effect of physical features, such as geology, soils, etc., did not have to be considered.

3-03. RESULTS OF THE STUDY

Development of double-mass curves of low flow over effective precipitation from these data indicated that low season flow has not been consistent in time. In all but one watershed (West Branch, Delaware, above Hale Eddy, which by observation shows less change in land use) the slope of the trend lines indicated that low season flow was increasing in time over and above any increase which would be explained by an increase in precipitation. By extending the trend lines of the early period (1915-25) to the present time and then by comparing them with the 1926-54 trend, it was possible to estimate what the change amounted to in units of run-off. Table 36 summarizes the results.

The test showed that in the five watersheds under study, where cover conditions have been improving with time, there has been no discernible change in the total water delivered other than would be expected or accounted for by variations in the annual amount of precipitation received. Further analysis of the records shows that low season flows have increased an average of 21 percent from 1915 to 1954. It is inferred that this change is due to cover condition improvement which has occurred on the watershed. In units of run-off, this increase amounts to an average of 40 acre-feet of water added to the low season flow per square mile of drainage area.

TABLE 36. INCREASE IN LOW SEASON FLOW IN STUDY WATERSHEDS 1/
DELAWARE RIVER BASIN

Watershed	Drainage Area	Run-off From The Watershed	Discharge 2/	Total Yield	Increase 3/
	Square Miles	Inches	Cubic Feet Per Second	Acre Feet	Percent
Beave[illegible]	241	1.10	58	14,137	17
East Branch, Delaware River	783	.50	86	20,880	9
Delaware River, above Port Jervis, N. Y.	3,076	.78	525	127,962	24
Bush Kill	117	1.31	33	8,174	34
Average		.92	175	42,789	21
Per Square Mile		.92	0.167	40.6	

1/ The change in low season flow on the West Branch of the Delaware, above Hale Eddy, has not been itemized. It is weighted in the average because the Port Jervis gage measures this flow.
2/ Fifty c.f.s. per day equals 538,603 gallons.
3/ See page 163 of this chapter.

Study results can be associated only with a general improvement in cover conditions and management which is known to have occurred. The study did not attempt to project the future trend in low season flows. However, since cover conditions in these watersheds can still be improved, it is reasonable to assume that these trends will continue as cover conditions improve.

It is not anticipated that hydrologic conditions over the entire Basin will show the rapid improvement or the degree of improvement found in the record of these study watersheds. This conclusion is based on two premises. First, hydrologic conditions in the areas studied were relatively poor at the beginning of the period and rapid improvement took place within the 40 years of record. This will not be a universal condition over the Delaware River Basin in the future. Second, no dramatic shifts in the use of the land (as from farm land to urban area) took place in the study watersheds. As pointed out in Chapter V, soil and cover combinations will change from sub-watershed to sub-watershed and within sub-watersheds in the time period considered. Changes in cover brought about by shifts in land use will be significant in many sub-watersheds.

SECTION IV - URBAN DEVELOPMENT AND ITS EFFECT ON STREAMFLOW

The trend in the watershed is to increase the number of houses, roads, etc., each year. As more homes are constructed, there will be fewer acres protected with a good vegetative cover. This trend will tend to increase peak flows and decrease low flows, infiltration and ground water recharge in those areas where urban and industrial developments cover an increasing percentage of the watershed. For example, changing a 50-acre area from a rotation of corn-small grain-meadow, on Hydrologic Group B soil, to roads and rooftops may increase the peak flows and storm run-off by as much as 30 percent for a 6 inch rainfall in 24 hours. Compensating factors, such as undersized storm sewers and restricted culverts and channels, may result in backwater with resulting reductions in peak flow.

SECTION V - LAND TREATMENT AND ITS EFFECT ON STREAMFLOW

Landowners and operators are showing an increasing interest in better land management, which includes conserving soil and water, managing forest lands, stabilizing upstream channels, and controlling excessive erosion and run-off from the uplands.

Land treatment measures have a greater effect on storms of long duration and low intensities than on storms of greater magnitude and higher intensities. Changes in land treatment measures have very little effect on peak flows in large rivers.

The decrease in peak flows varies with the quantity of precipitation and the duration of the storm and is not consistent for all streams. It is mainly dependent upon the geologic formations within the watershed. In a few isolated areas under certain geologic conditions there is no sub-surface, quick return flow. In these areas there would be a lesser reduction of peak flows. Other geologic formations are such that

water which has been retarded and has infiltrated into the soil will reappear and contribute to peak flows further downstream. The amount of this water that will reappear downstream varies from stream to stream and should be studied on an individual watershed basis.

To project what effect changes in land treatment measures will have on low flows, annual yields and peak flows for the different time periods, large numbers of varied and complicated parameters must be considered. These combinations of soil, cover, urban development, etc., are included in the index numbers shown in Table 37 for the different problem areas (see Chapter II, Fig. 10) for the four time periods. Figure 14 indicates the run-off changes reflected by a 1 point change in the index number.

As a result of improved land conditions, additional water goes into the soil through infiltration to recharge the ground water, part of which will appear later as springs, increasing and prolonging the low flows. The remainder will go back to the air through evapo-transpiration.

Table 37 is a summary of the soil-cover complex index numbers for each of the problem areas for 1975, 2010 and 2060. These index numbers represent the composite effect of the projected soils and covers for the respective periods. This takes into consideration all the trends of urbanization and agriculture.

The index number for Problem Area 1 changes from 69.6 for present conditions to 63.9 for the year 2060, as the result of improved cover and management. This may result in a decrease of 18 percent in peak flow from a 6 inch rainfall in 24 hours on the upstream tributaries. The percent change decreases as the drainage area and stream length increases. This decrease is due in part to water which is "lost" through infiltration reappearing downstream as sub-surface base flow. The change in the index number is also an indication of change in total run-off and low flows. The greater the infiltration, the greater the low flow; but the annual yield may be somewhat less. However, these reductions in annual yield are usually too small to be detected by normal streamflow measurements. Based on small watershed studies, approximately half of the difference in infiltration will be reflected in the volume of return flow and the remaining half from transpiration and evaporation.

Each of the other five problem areas also has a decreasing soil complex index number as shown in Table 37. This presumes a better cover and management for the Delaware River Basin in the future, provided the present and expected trends in improved land management continue to accelerate. For the Basin as a whole, better cover and management are more than enough to offset the effect on peak flows, annual yields and low flows due to urbanization.

The analysis for Problem Area 1 shows a 6 percent increase in low flows by the year 2060. The annual yields will decrease very slightly

TABLE 37. SOIL-COVER COMPLEX INDICES BY PROBLEM AREAS
FOR PRESENT AND PROJECTED CONDITIONS
DELAWARE RIVER BASIN

Problem Area	Acreage	Years			
		Present	1975	2010	2060
		Run-off Index Numbers			
			*	*	*
1	2,483,976	69.6	68.3	65.9	63.9
2	613,766	70.3	68.7	67.8	65.9
3	605,692	73.6	72.8	71.7	70.1
4	620,915	74.8	73.4	72.5	71.5
5	1,397,198	76.2	75.2	74.5	73.7
6	1,739,522	72.6	71.9	71.0	70.7
Total	7,461,069 1/				

1/ The difference in total acres (8,169,600) is due to 708,531 acres in counties with less than 25 percent of their area in the Delaware River Basin.
*See Figure 14 for change in direct run-off associated with index number change of 1.0.

as the cover in the watershed improves. By the year 2060, the annual yield may decrease approximately 1-1/2 percent from the present. Table 38 shows the percent of change to be expected in low flows, peak flows and yields for each problem area by the year 2060.

Tables 39, 40 and 41 show the projections for soil and cover for the six problem areas for the years 1957, 2010 and 2060.

SECTION VI - EFFECT OF LAND TREATMENT ON SEDIMENTATION

The relationship between land use and sediment yield is discussed in Chapter VI. It is shown that a reduction in sediment production from the sediment source area will have a corresponding reduction in yield. It is evident from the data that the principal source of suspended sediment in the Delaware River Basin is sheet erosion. Sheet erosion from woodland and grassland ranges from 0.1 ton per acre per year to 2.5 tons per acre per year. Cropland soil losses range from 5.7 tons to 30.7 tons per acre per year. It is obvious that the most effective efforts toward the reduction of sediment yield will be related to a decrease in acreage of cropland, or reduction of soil loss from the cropland acreage, and the relocation of cropland from areas subject to erosion to areas less subject to erosion.

As shown in Chapter IV, there is a trend toward better management of the lands in the Delaware River Basin. The effects of better land management on sedimentation are exemplified by data from the Brandywine Creek watershed. In reports to the American Geophysical Union 1/, it was shown that an installation of approximately 25 percent of the needed conservation practices was accompanied by a 38 percent decrease in sediment concentration at Wilmington, Delaware.

Based on the expected use of the land as shown in Table 40, Table 42 was developed to show the effect of the land use changes and management improvement on sheet erosion.

It is significant that the largest reduction in sheet erosion is expected in the problem areas where urban growth will be the greatest. Urbanization of rural areas has a definite impact on sediment yield. During the time of development, erosion and sediment yield are deemed to be many times higher than under agricultural management. With the establishment of lawns, pavements and storm sewers, the rate is stabilized at a significantly lower figure.

1/ Land Use Trends In The Brandywine Watershed, Busch, Howard and Hall, G. Robert, A.G.U., 1958; and The Trend of Suspended-Sediment Discharge Of The Brandywine Creek at Wilmington, Delaware, 1947-1955, Guy, H. P., open file report, U. S. Geological Survey.

TABLE 38. PERCENT CHANGE IN PEAK AND LOW FLOWS AND YIELDS, PRESENT TO 2060
UPSTREAM TRIBUTARIES, DELAWARE RIVER BASIN

Problem Area	Present Index Number	2060			
		Future Index Number	Low Flows	Peak Flows	Annual Yield
			Percent Increase	Percent Decrease 1/	Percent Decrease
1	69.6	63.9	6.0	18	1.5
2	70.3	65.9	4.6	14	1.2
3	73.6	70.1	3.7	11	1.0
4	74.8	71.5	3.5	10	0.9
5	76.2	73.7	2.6	7	0.7
6	72.6	70.7	2.0	6	0.5

1/ Based on 6 inches of rainfall in 24 hours.

TABLE 39. LAND USE ESTIMATE, 1975
DELAWARE RIVER BASIN

(1) Prob. Area	(2) Hydro-logic Soil Group	(3) Cropland Acres	(4) Cropland Index Number	(5) (3)x(4)	(6) Pasture Acres	(7) Pasture Index Number	(8) (6)x(7)	(9) Woodland Acres	(10) Woodland Index Number	(11) (9)x(10)	(12) Idle Acres	(13) Idle Index Number	(14) (12)x(13)	(15) Urban Acres	(16) Urban Index Number 1/	(17) (15)x(16)	(18) Wgt. Run-off Index Number
1	A	23,731	64.1	1,521,157	10,320	48.0	495,360	39,832	39.0	1,553,448	4,875	68.0	331,500	16,055	70.6	1,133,483	
	B	150,525	71.5	10,762,538	69,969	68.1	4,764,889	1,036,233	63.0	65,282,679	34,483	79.0	2,724,157	128,738	70.2	9,037,407	
	C	94,827	80.6	7,643,056	40,648	74.4	3,024,211	650,221	72.0	46,815,912	19,206	86.0	1,651,716	164,421	81.0	13,318,101	68.3
	Total	269,083		19,926,751	120,937		8,284,460	1,726,286		113,652,039	58,564		4,707,373	309,214		23,488,991	
2	A	3,643	55.6	202,551	133	48.0	6,384	1,870	39.0	72,930	1,083	68.0	73,644	722	54.2	39,132	
	B	153,015	67.8	10,374,417	26,540	68.1	1,807,374	196,531	62.0	12,184,922	41,793	78.4	3,276,571	71,344	73.9	5,272,322	
	C	35,864	76.4	2,740,010	8,966	78.0	699,348	41,515	72.0	2,989,080	14,949	86.0	1,285,614	11,035	78.0	860,730	68.7
	D	1,965	82.1	161,327	437	83.0	36,271	1,171			600	89.0	53,400	603	68.7	41,426	
	Total	194,487		13,478,305	36,076		2,549,377	241,087		15,246,932	58,425		4,689,229	83,704		6,213,610	
3	A	8,429	60.2	507,426	546	48.0	26,208	4,798	43.0	206,314	1,020	68.0	69,360	1,199	55.7	66,784	
	B	93,129	68.0	6,332,772	5,199	68.0	353,532	93,698	65.0	6,090,370	10,692	79.0	844,668	16,437	68.1	1,119,360	72.8
	C	84,090	77.6	6,525,384	9,277	78.0	723,606	212,581	75.0	15,943,575	11,135	86.0	957,610	53,461	80.7	4,314,303	
	Total	185,648		13,365,582	15,022		1,103,346	311,077		22,240,259	22,847		1,871,638	71,097		5,500,447	
4	B	138,713	70.3	9,751,524	22,893	68.0	1,556,724	64,649	62.0	4,008,238	11,753	79.0	928,487	27,350	70.7	1,933,645	
	C	129,223	78.5	10,144,006	25,293	78.0	1,972,854	120,780	72.0	8,696,160	8,583	85.7	735,563	71,220	81.3	5,790,186	73.4
	Total	267,936		19,895,530	48,186		3,529,578	185,429		12,704,398	20,336		1,664,050	98,570		7,723,831	
5	B	277,358	70.9	19,664,682	28,935	68.0	1,967,580	67,530	63.0	4,254,390	27,611	79.0	2,181,269	205,707	81.4	16,744,550	
	C	317,759	78.2	24,848,754	75,274	78.0	5,871,312	260,543	73.0	19,019,639	37,111	86.0	3,191,546	74,084	78.1	5,785,960	
	D	7,538	82.5	621,885	1,673	83.0	138,859	4,491	79.0	354,789	2,303	89.0	204,967	9,264	21.4	198,250	75.2
	Total	602,655		45,135,321	105,882		7,977,811	332,564		23,628,818	67,025		5,577,782	289,055		22,728,760	
6	A	42,965	64.6	2,775,539	2,242	48.0	107,616	42,082	41.0	1,725,362	19,338	68.0	1,314,984	18,293	57.0	1,042,701	
	B	355,698	74.8	26,606,210	34,843	68.0	2,369,324	418,511	64.0	26,784,704	56,659	79.0	4,476,061	151,984	71.0	10,790,864	
	C	140,180	82.3	11,536,814	13,019	78.0	1,015,482	88,698	74.0	6,563,652	19,985	86.0	1,718,710	333,636	78.4	26,157,062	71.9
	D										1,188	89.0	105,732	201	89.0	17,889	
	Total	538,843		40,918,563	50,104		3,492,422	549,291		35,073,718	97,170		7,615,487	504,114		38,008,516	

1/ Chapter VII explains why curve number decreases.

TABLE 40. LAND USE ESTIMATE, 2010
DELAWARE RIVER BASIN

(1) Prob. Area	(2) Hydrologic Soil Group	(3) Cropland Acres	(4) Cropland Index Number	(5) (3)x(4)	(6) Pasture Acres	(7) Pasture Index Number	(8) (6)x(7)	(9) Woodland Acres	(10) Woodland Index Number	(11) (9)x(10)	(12) Idle Acres	(13) Idle Index Number	(14) (12)x(13)	(15) Urban Acres	(16) Urban Index Number 1/	(17) (15)x(16)	(18) Wgt. Run-off Index Number
1	A	23,013	63.0	1,449,819	10,008	47.0	470,376	38,627	36.0	1,390,572	4,727	68.0	321,436	18,438	68.3	1,259,315	
	B	145,969	70.5	10,290,815	67,851	67.0	4,546,017	1,004,866	59.0	59,287,094	33,439	79.0	2,641,681	167,824	69.2	11,613,421	65.9
	C	91,957	79.6	7,319,777	39,418	73.5	2,897,223	630,539	69.0	43,507,191	18,624	86.0	1,601,664	188,785	80.3	15,159,436	
	Total	260,939		19,060,411	117,277		7,913,616	1,674,032		104,184,857	56,790		4,564,781	375,047		28,032,172	
2	A	3,344	54.6	182,582	122	47.0	5,734	1,717	37.0	63,529	994	68.0	67,592	1,274	54.2	69,051	
	B	140,476	66.8	9,383,797	24,365	67.0	1,632,455	180,425	60.0	10,825,500	38,368	78.4	3,008,051	105,589	72.1	7,612,967	
	C	32,925	75.4	2,482,545	8,231	77.0	633,787	38,112	70.0	2,667,840	13,724	86.0	1,180,264	19,337	78.5	1,517,955	67.8
	D	1,804	81.1	146,304	401	82.0	32,882	1,075			551	89.0	49,039	945	64.8	61,236	
	Total	178,549		12,195,228	33,119		2,304,858	221,329		13,556,869	53,637		4,304,946	127,145		9,261,209	
3	A	7,262	59.2	429,910	470	47.0	22,090	4,134	41.0	169,494	879	68.0	59,772	3,247	55.7	180,857	
	B	80,242	67.0	5,376,214	4,480	67.0	300,160	80,732	63.0	5,086,116	9,213	79.0	727,827	44,488	68.1	3,029,633	71.7
	C	72,454	76.6	5,549,976	7,993	77.0	615,461	183,164	73.0	13,370,972	9,594	86.0	825,084	97,339	79.1	7,699,515	
	Total	159,958		11,356,100	12,943		937,711	268,030		18,626,582	19,686		1,612,683	145,074		10,910,005	
4	B	127,346	69.3	8,825,078	21,017	67.0	1,408,139	59,351	60.0	3,561,060	10,790	79.0	852,410	46,854	70.3	3,293,836	
	C	118,633	77.5	9,194,058	23,220	77.0	1,787,940	110,882	70.0	7,761,740	7,880	85.7	675,316	94,484	80.4	7,596,514	72.5
	Total	245,979		18,019,136	44,237		3,196,079	170,233		11,322,800	18,670		1,527,726	141,338		10,890,350	
5	B	243,109	69.9	16,993,319	25,362	67.0	1,699,254	59,191	61.0	3,610,651	24,201	79.0	1,911,879	255,278	79.4	20,269,073	
	C	278,521	77.2	21,501,821	65,979	77.0	5,080,383	228,370	71.0	16,214,270	32,528	86.0	2,797,408	159,373	78.2	12,462,969	74.5
	D	6,607	81.7	539,792	1,466	82.0	120,212	3,936	77.0	303,072	2,019	89.0	179,691	11,240	32.4	364,176	
	Total	528,237		39,034,932	92,807		6,899,849	291,497		20,127,993	58,748		4,888,978	425,891		33,096,218	
6	A	41,457	63.6	2,636,665	2,163	47.0	101,661	40,606	39.0	1,583,634	18,659	68.0	1,268,812	22,035	56.5	1,244,978	
	B	343,217	73.8	25,329,415	33,620	67.0	2,252,540	403,827	62.0	25,037,274	54,671	79.0	4,319,009	182,360	70.9	12,929,324	
	C	135,261	81.3	10,996,719	12,562	77.0	967,274	85,586	72.0	6,162,192	19,284	86.0	1,658,424	342,825	78.4	26,877,480	71.0
	D										1,146	89.0	101,994	243	89.0	21,627	
	Total	519,935		38,962,799	48,345		3,321,475	530,019		32,783,100	93,760		7,348,239	547,463		41,073,409	

1/ Chapter VII explains why curve number decreases.

TABLE 41. LAND USE ESTIMATE, 2060
DELAWARE RIVER BASIN

(1) Prob. Area	(2) Hydro-logic Soil Group	(3) Cropland	(4) Cropland	(5) (3)x(4)	(6) Pasture	(7) Pasture	(8) (6)x(7)	(9) Woodland	(10) Woodland	(11) (9)x(10)	(12) Idle	(13) Idle	(14) (12)x(13)	(15) Urban	(16) Urban	(17) (15)x(16)	(18) Wgt. Run-off Index Number
		Acres	Index Number		Acres	Index Number		Acres	Index Number		Acres	Index Number		Acres	Index Number 1/		
1	A	19,139	62.1	1,188,532	8,323	46.0	382,858	38,400	33.0	1,267,200	3,931	68.0	267,308	25,020	66.2	1,656,324	
	B	121,397	69.6	8,449,231	56,429	66.0	3,724,314	999,136	56.0	55,951,616	27,810	79.0	2,196,990	215,177	67.7	14,567,483	
	C	76,477	78.6	6,011,092	32,782	72.5	2,376,695	626,942	66.0	41,378,172	15,489	86.0	1,332,054	217,633	80.2	17,454,167	63.9
	Total	217,013		15,648,855	97,534		6,483,867	1,664478		98,596,988	47,230		3,796,352	457,830		33,488,991	
2	A	2,880	53.6	154,368	105	46.0	4,830	1,988	34.0	67,592	856	68.0	58,208	1,622	58.1	94,238	
	B	120,989	65.8	7,961,076	20,985	66.0	1,385,010	208,869	57.0	11,905,533	33,045	78.4	2,590,728	105,335	73.5	7,742,123	
	C	28,358	74.4	2,109,835	7,089	76.0	538,764	44,122	67.0	2,956,174	11,820	86.0	930,520	20,940	79.5	1,664,730	65.9
	D	1,554	80.1	124,475	346	81.0	28,026	1,246			475	89.0	42,275	1,155	81.7	94,364	
	Total	153,781		10,349,754	28,525		1,956,630	256,225		14,929,299	46,197		3,621,731	129,052		9,595,455	
3	A	5,886	58.2	342,565	381	46.0	17,526	4,362	38.0	165,756	712	68.0	48,416	4,651	58.2	270,688	
	B	65,039	66.0	4,292,574	3,631	66.0	239,646	85,319	60.0	5,119,140	7,467	79.0	589,893	57,699	68.9	3,975,461	
	C	58,727	75.6	4,439,761	6,479	76.0	492,404	193,584	70.0	13,550,880	7,777	86.0	668,822	103,977	79.4	8,255,774	70.1
	Total	129,652		9,074,900	10,491		749,576	283,265		18,835,776	15,956		1,307,131	166,327		12,501,923	
4	B	109,680	68.3	7,491,144	18,101	66.0	1,194,666	54,548	57.0	3,109,236	9,293	79.0	734,147	73,736	70.3	5,183,641	
	C	102,176	76.5	7,816,464	19,999	76.0	1,519,924	101,906	67.0	6,827,702	6,787	85.7	581,646	124,231	79.9	9,926,057	71.5
	Total	211,856		15,307,608	38,100		2,714,590	156,454		9,936,938	16,080		1,315,793	197,967		15,109,698	
5	B	215,587	68.9	14,853,944	22,491	63.0	1,416,933	52,934	58.0	3,070,182	21,462	79.0	1,695,498	294,667	78.3	23,072,426	
	C	246,990	76.2	18,820,638	58,509	76.0	4,446,684	204,227	68.0	13,887,436	28,846	86.0	2,480,756	226,199	78.2	17,688,762	73.7
	D	5,859	80.7	472,821	1,300	81.0	105,300	3,519	74.0	260,406	1,790	89.0	159,310	12,800	38.6	494,080	
	Total	468,436		34,147,403	82,300		5,968,917	260,680		17,218,014	52,098		4,335,564	533,666		41,255,268	
6	A	38,543	62.6	2,412,792	2,011	46.0	92,506	24,711	37.0	914,307	17,347	68.0	1,179,596	42,308	52.0	2,200,016	
	B	319,088	72.8	23,229,606	31,257	66.0	2,062,962	245,762	60.0	14,745,720	50,828	79.0	4,015,412	370,760	68.8	25,508,288	
	C	125,752	80.3	10,097,886	11,679	76.0	887,604	52,087	70.0	3,646,090	17,928	86.0	1,541,808	388,072	78.3	30,386,038	70.7
	D										1,065	89.0	94,785	324	89.0	28,836	
	Total	483,383		35,740,284	44,947		3,043,072	322,560		19,306,117	87,168		6,831,601	801,464		58,123,178	

1/ Chapter VII explains why curve number decreases.

TABLE 42. SHEET EROSION PER SQUARE MILE (TONS PER YEAR)
DELAWARE RIVER BASIN

Problem Area	Present	Year 2060	Reduction
			Percent
1	877	650	25
2	2,010	1,190	41
3	2,335	960	59
4	3,134	810	74
5	2,484	1,280	48
Weighted (against area) average			42

SECTION VII - TYPES AND EFFECTS OF STRUCTURAL MEASURES

Upstream works of improvement, including land treatment and structural measures on the minor tributaries, are considered an integral part of the comprehensive plan for the development of the Delaware River Basin.

The need for upstream measures is shown in Chapter VIII.

7-01. TYPES OF STRUCTURAL MEASURES

a. Land Treatment and Minor Structural Measures for Flood Prevention. These measures, primarily for flood prevention, usually consist of vegetative and minor structural control, such as tree planting, seeding, sodding, establishment of shrubs and vines; such minor structural items as special purpose terraces, minor check dams and gully plugs, desilting and debris basins, drop inlets, chutes and diversions for stabilization of critical run-off and sediment producing areas, gullies and minor waterways; the installation of firebreaks, towers, roads, and shelters; and the provision of equipment for increased fire protection to serve flood prevention purposes.

The effect of other interrelated land treatment measures, such as contour cultivation, strip cropping, diversions, sod waterways, crop rotations, forest management, pasture management, etc., is shown in previous paragraphs of this chapter. Computations were made through the modification of the hydrologic indices. In summary form, the effects anticipated are shown in Table 38.

b. Reservoirs

(1) Detention Reservoirs. Detention storage reservoirs detain run-off water during periods of heavy run-off and discharge the water slowly. The type considered by the Department of Agriculture is more fully described in Appendix R.

(2) Retention Reservoirs. Retention storage reservoirs are primarily for storing water for future use, such as municipal water supply, recreation and irrigation.

(3) Multi-Purpose Reservoirs. Multi-purpose reservoirs are designed for two or more purposes and may contain features of both detention and retention storage.

c. Channel Improvement, Dikes, and Levees. These structures are installed in a particular locality for protection near the point of installation. Channel improvement and stabilization is intended to safely increase

the capacity of the channel.

Dikes and levees are designed to confine streamflow to a definite width for the protection of adjoining land from overflow.

7-02. INVENTORY OF POTENTIAL STRUCTURAL MEASURES

As shown in Chapter VIII, floodwater detention storage is needed at the present time in many parts of the Delaware River Basin.

The reservoir sites considered for this study were those with drainage areas of one square mile or more. In addition, there is a need for many reservoirs on sites with less than one square mile of drainage area. Studies completed on five watersheds within the Delaware River Basin, under Public Law 566 authorization, indicate that one of the smaller reservoirs is needed to supplement two of the larger ones. Table 43 is a summary of the flood control structures in the five watersheds.

A total of 319 potential upstream reservoir sites were located by map analysis and field investigations. The map study was not completed in watersheds being considered under P. L. 566 program. A total of 75 sites were found to be justified for flood prevention reservoirs. Table 44 is a summary of pertinent data related to these sites. Many of the remainder (244) are sites which some time in the future, or in conjunction with mainstem reservoirs, may be developed for low flow augmentation, water supply, recreation, or flood control. These 244 upstream reservoirs have a total storage potential of about 528,776 acre-feet.

The status of the program, under the Watershed Protection and Flood Prevention Act (P. L. 566), in the Delaware River Basin is shown in Table 45 and in Figure 15. In addition to the dams, channel improvement and other interrelated measures are planned in these watersheds. Of particular significance is the consideration given to land treatment measures, both for watershed protection and flood prevention in these watershed plans. In effect, the watershed land treatment is supplemented and complemented by the structural measures in these small watersheds in somewhat the same manner as the upstream reservoirs supplement and complement the reservoirs proposed for the larger tributaries.

7-03. EFFECT OF STRUCTURAL MEASURES

a. Effects on Peak Flows

(1) Effect on High and Low Flow of Floodwater Retarding Structures. There are two ways of mitigating the upstream-type of flooding. The first is by better land management, which has been

TABLE 43. STATISTICS ON WATERSHED PROJECTS
(PUBLIC LAW 566 PLANS PREPARED)
AS OF JUNE 30, 1959
DELAWARE RIVER BASIN

Total Number Of Plans Prepared		5 1/
Range Of Size Of Watershed Area	42 Sq.Mi.-330 Sq.Mi.	
Floodwater Retarding Dams	No.	40 2/
Total Storage In Sediment Pool	Ac.-Ft.	1,894
Total Detention Storage	Ac.-Ft.	30,553
Height Of Dams From 11 To 70 Feet	Av. Ft.	35
Cubic Yards Of Fill From 2,000 To 380,000	Total	4,124,000
Average Volume Of Fill	Cu. Yds.	100,000
Average Federal Cost Per Project		$1,484,800
Average Local Cost Per Project 3/		1,549,600
Average Total Cost Per Project 3/		3,034,400

1/ Does not include Town Bank watershed in New Jersey, which involves no reservoirs.
2/ Fourteen of these structures are on sites with less than 1 square mile of drainage area.
3/ Includes water management costs.

TABLE 44. SUMMARY OF UPSTREAM RESERVOIRS
DELAWARE RIVER BASIN

Sub-basin	Dams	Controlled Drainage Area	Detention Storage	Average Annual Benefit	Average Annual Cost
	Number	Square Miles	Acre-Feet	Dollars	Dollars
1	3	28	5,888	40,214	22,346
2					
3	14	50	11,243	176,803	114,322
4	31	103	21,896	491,124	268,015
5	2	9	1,877	29,215	17,195
6	2	27	5,803	39,658	12,983
7	4	31	6,676	58,858	26,667
8	9	44	10,684	102,428	78,921
9	10	70	14,860	125,356	94,793
Total	75	362	78,927	1,063,656	635,242

TABLE 45. STATUS OF PUBLIC 566 WATERSHED PROJECTS[1]
AS OF JUNE 30, 1959
DELAWARE RIVER BASIN

	Area Square Mile
Applications Received:	
Acquashicola Watershed, Pennsylvania	83
Mauch Chunk Watershed, Pennsylvania	9
Tobyhanna Watershed, Pennsylvania	83
Watersheds Having Favorable Preliminary Examination:	
Wissahickon Creek, Pennsylvania	54
Pocono Creek, Pennsylvania	50
Watersheds Being Planned:	
Brodhead Creek, Pennsylvania	141
Watersheds With Planning Completed:	
*Paulins Kill, New Jersey	171
*Lackawaxen Tributaries, Pennsylvania	42
Green Dreher, Pennsylvania	75
*Little Schuylkill, Pennsylvania	136
Brandywine, Pennsylvania	330
*Town Bank, New Jersey	3.7

1/ In addition, the Pequest watershed, involving channel improvement only, was constructed as a pilot project.
* These watersheds have been approved for operation.

discussed at length in previous paragraphs. The second, which is used to supplement land treatment, is the use of floodwater retarding structures, controlling run-off from drainage areas varying from a few acres to several square miles. Floodwater retarding structures in the Public Law 566 program in the Delaware River Basin have usually been designed to retain 4 inches of run-off from the watershed above the structure which is about the amount of run-off to be expected from a single storm occurrence of once in 100 years. Storm water on the upstream tributaries above such structures, which formerly ran off in a few hours, will now take several days. This reduces the peak discharge from the reservoir to the release rate of the principal spillway for storms less than 100-year frequency. For storms greater than 100-year frequency, there will be additional discharge through the emergency spillway.

The reduction in damages or the degree of protection varies with the area of the watershed controlled by the structure. Protection will be almost 100 percent near the dam, decreasing to about 5 percent (or to zero) at some point 10 to 20 miles downstream. A damage reach in the flood plain thus is benefited inversely in proportion to its distance from the dam or group of dams. Figure 16 is a schematic hydrograph of a storm coming into and leaving a floodwater retarding structure.

In a typical watershed with a total drainage area of 48 square miles where three structures are planned, the following reductions in peak flows for different degrees of area controlled are computed:

Reach	Drainage Area Above Reach	Drainage Area Controlled	Percent Controlled	Percent Reduction In Peak Flows
	Square Miles	Square Miles		
A	5	5	100	93
B	19	13	68	53
C	29	17	59	42
D	38	17	45	27

With the installation of enough structures, the peak flow can be materially reduced with a consequent reduction in damages along the tributaries. Figure 17 shows a typical hydrograph at a damage point before and after the installation of structures.

b. Effect on Water Yield. The effect of the upstream reservoirs on low flows and annual yields will vary with geographical location and geology at the site. In some small watersheds, where a complete program has been installed, there has been a noticeable increase in low flows. For example, since the installation of the program on Salem Fork, West Virginia, observations indicate that small tributaries which

formerly had no flow in dry weather now have a considerable amount.

A study was made of one upstream reservoir on yield and low flow. This study was made at the Terry Clove Kill U. S. Geological Survey gage (drainage area, 14.1 square miles), near Pepacton, New York. For this study, it was assumed that no water was lost due to seepage.

The study consisted of routing the entire two-year flow through the structure. One of these was a dry year and the other a year of above average run-off. Evaporation from the surface of the permanent pool was subtracted each day.

Conclusions from this study indicate that the low flow is increased appreciably for a few days after each major storm. In the study for the wet year, the mean daily flow increased by less than 1 percent. In the study for the dry year, the mean daily flow decreased. In each study, the base flow into the reservoir was of sufficient volume to sustain an outflow through the principal spillway for the entire period of the study. Total evaporation from the pool was insignificant compared to the total volume of inflow. Other locations, however, with evaporation from the pool greater than base flow coming into the reservoir, will probably show long periods of time without flow from the structure.

Geologic conditions in the tributary valleys of the Delaware River Basin have been influenced to a marked degree by outwash from the glaciated areas. Deep valley fills are the rule rather than the exception in the Delaware River Basin. Foundation studies for Dyberry Dam, near Honesdale, Pennsylvania, revealed about 110-115 feet of sand, silt and gravel in the valley. The presence of appreciable amounts of permeable materials have been found in most tributaries in the Delaware River Basin. Percolation under the dams is adequately controlled to prevent danger to the structure. This control is attained by cutoff walls, toe drains and relief wells which act to collect the diffused percolating water and return it safely to the stream. It is probable, where dams are built, that sustained flow will be attained in many channels that are dry much of the year under present conditions.

The U. S. Weather Bureau study of evaporation rates in the Delaware River Basin indicates a range of 37 inches in the south to 28 inches over the Appalachian Plateaus. The evaporation from the conservation pools and a small portion of this storage seeping into deep aquifers may leave a slightly less total annual yield from the watershed. The increased evaporation from the pool is considered to be insignificant, since a large amount of evapo-transporation would have taken place from the vegetation in the pool area and the water surface area within the stream channel.

c. Effect on Sedimentation. Sediment loads 1/ correlate with the

1/ USGS-SCS Sedimentation Study.

use of the land in the Delaware River Basin. In the forested area, the watersheds, such as Bush Kill near Stroudsburg, carry suspended sediment loads of about 30-40 tons per square mile per year. The other extreme, as shown by agricultural areas such as Brandywine Creek, show suspended load of about 180-200 tons per square mile per year. Neshaminy Creek, with an appreciable encroachment of urbanization on an agricultural watershed, shows a high sedimentation rate amounting to about 260 tons per square mile per year. Previous paragraphs of this chapter show the potential control of suspended sediment load possible through land treatment measures.

Storage reservoirs capture an appreciable amount of the remaining sediment load. The usual design of floodwater detention reservoirs allows for the trapping of at least 90 percent of the incoming suspended sediment. In addition, upstream reservoirs will usually stabilize the geometry of the stream channels and reduce the problems related to coarse sediments that originate from the channels.

Coarse sediments cause particularly acute problems in the steeper tributaries as shown in Chapter IV. Much of this damage can be eliminated by control of the sources of these materials. Since most of these sediments originate from sources other than sheet erosion, conservation measures on the land will not yield the desired effect on these occurrences. Streambank erosion control, channel stabilization with grade control structures, rip-rap, and vegetation will be required as supplementary measures to the land treatment before a satisfactory level of control is attained.

USE AND MANAGEMENT OF LAND AND COVER RESOURCES OF THE DELAWARE RIVER BASIN

CHAPTER X

SUMMARY AND CONCLUSIONS

SECTION I - INTRODUCTION

Expanding communities in, or adjacent to, the Delaware River Basin are creating new demands and causing new problems. Many of the changes brought about by expansion are adverse to the "natural" water-soil-plant-animal balance and seriously affect the interrelationships inherent in a drainage basin. These changes serve to sharply reduce the watershed's ability to regulate flow and the stream's ability to cleanse water as it passes through the various reaches.

Continued population growth and expansion of communities require the installation of planned developments that will make compensations for such changes in basin conditions and provide optimum quantities of suitable quality water. The plan should provide for the economical control of damages caused by floods and coordinate land management, water demands and water supplies into an integrated multiple-purpose program.

Users of rural lands need to manage their lands so they contribute to an over-all program of water conservation and water regulation. Users of rural lands also have increasing needs for water for domestic use, the growing of irrigated crops and livestock production.

As the natural cover on the land is changed or destroyed, or replaced with houses and streets, the rainfall-run-off relationships change. As a result, normal precipitation causes high run-off which, if uncontrolled, may cause floods of disastrous proportions. Uncontrolled flow from high run-off-producing areas also results in a high percentage of the Basin's water yield flowing to the ocean without opportunity for use.

Most land in the Delaware River Basin will continue to be used for cropland, pasture, and forest or woodland. However, the trend to nonagricultural uses in some areas will require adjustments beyond the ability of landowners themselves. This is especially true if flood protection is to be provided in conjunction with an increased supply of water for a greater variety of uses and a larger number of people.

SECTION II - SUMMARY OF FINDINGS AND PROJECTIONS

2-01. MAJOR WATER PROBLEMS

The major water problems of the Delaware River Basin are the result of

three factors: an imbalance in seasonal run-off, inadequate water storage facilities in the proper locations, and unusual concentration of people.

The average minimum run-off from segments of the Basin during the summer months is barely adequate to meet present needs. The high proportion of annual water yield that occurs as winter and spring run-off results in frequent flooding on small tributary streams. Lack of adequate and well-located storage facilities limits the opportunity for storage during periods of excessive run-off to meet dry season shortages.

Basin-wide floods occur infrequently in the Delaware River Basin, but they do occur. In the 18th century, one flood of Basin-wide importance produced a discharge of 177,000 c.f.s. at Trenton, New Jersey. 1/ In the 19th century, three floods produced discharges above 150,000 c.f.s. at Trenton. In the 20th century, nine floods produced greater than the zero-damage stage, the most recent one being in 1955, which produced a discharge of 329,000 c.f.s. at Trenton. It was the most destructive flood of record, partly because there was more development in the flood plain.

Many of the tributaries experience frequent floods that cause considerable land and property damage. Although floodwater damages that occur on any individual minor tributary are small in comparison to those in larger tributaries and the mainstem reaches of the Delaware River, the intensity of damages per square mile of drainage area is comparable.

Floodwater damages in these small watersheds often attract little attention outside the immediate area. This may lead to a conclusion that such damages are of minor importance. To the individuals involved, however, severe economic losses occur. For the Delaware River Basin as a whole, the sum of such damages represents a substantial economic loss.

Too little water also results in serious economic losses. These losses may be in the form of decreased agricultural production, curtailment of industrial output, and costly supplemental water supplies. Recreation and pollution abatement are both adversely affected by low flows.

2-02. LAND USE DEVELOPMENT

The Delaware River Basin is still predominately rural; only 10 percent of its area is used for urban and industrial purposes. However, the form of rural use has changed materially over the years. Originally, the Basin was densely forested with fine stands of timber which provided the optimum conditions for natural control of run-off and soil erosion. Clearing and cultivation of farmland and overuse of the remaining forest has removed, or changed, much of this natural cover, resulting in increased erosion and reduced infiltration of surface water into the soil.

1/ A discharge of 150,000 c.f.s. is considered to just reach the stage of zero-damage at Trenton.

The early settlers cleared and burned much of the forest to make way for homes and farms. The resources were freely used. The timber was cut without regard to future production. Although nearly 50 percent of the Basin is still in forest, the stands now are mainly young and poorly stocked and are well below their potential for regulating streamflows, reducing floods, and filling ground reservoirs.

Many areas cleared for farming were farmed without regard to loss of soil by erosion and the effect of sedimentation on the streams. These changes in land use have had a continuous and marked effect on the hydrology of the Basin.

Many changes were inevitable in the normal development of the Basin. In other instances, due to the abundance of natural resources, the possible consequences of the exploitation were not fully realized or appreciated. It is only recently, due to increasing pressure from industrial development and higher standards of living, that inadequacies of the supply of land and water resources have been brought sharply into focus.

2-03. MAJOR FACTORS IN THE PRESENT LAND USE

One of the outstanding characteristics of the Delaware River Basin is the diversity of its physiographic features--soil, topography and climate. This diversity has led to a like diversity in the production of farm products and other present uses of lands.

The northern part of the Basin has mountainous topography; shallow, wet soils; and short, cool growing seasons. About 70 percent of the area, or 2,529,000 acres, is in forest, as compared to about 50 percent for the Basin as a whole. Being adjacent to large centers of population, it has become one of the country's most popular recreational areas. The limited farming is largely dairy production since the short, cool growing season and wet soils are best adapted to the production of grass. Dairying has become increasingly important as the population has increased.

The central section of the Basin consists of gently rolling to hilly topography, with soils of high productive capacity. These factors, together with a somewhat milder climate, make the area suitable for intensive farming. As a result, 45 percent, or 1,283,800 acres, is in cropland. The more gentle slopes lend themselves to the use of labor-saving machinery and equipment. This is an area where a variety of crops are grown. Some specialization in potatoes, fruit, and canning crops has developed; but being near large markets, dairying, poultry and vegetable farming are predominant.

Much of the Coastal Plain consists of flat, sandy land. The productive soils are easily worked and managed and are adapted to the

production of vegetables or other intensively grown crops. Here woodlands constitute only 37 percent, or 647,600 acres, of the area. They are mainly found on the wet soils. The common observation that the best agricultural lands are most affected by urban expansion is borne out here. The urban area in the Coastal Plain is in the highest proportion to total area of any of the above three regions. The urban area consists of almost 17 percent of the Coastal Plain region, as compared with 9 percent of the central portion and 5 percent of the northern portion.

2-04. LAND USE AS A FACTOR IN WATER PRODUCTION

Complex relationships exist between vegetative cover, the use and treatment of cover, type of soil, and water run-off. Under most systems of management, land cropped to grass and trees presents a less serious erosion and run-off problem than similar land devoted to cultivated crops. Erosion is practically non-existent on land protected by adequate plant cover. As plant cover deteriorates, erosion and run-off losses become progressively higher.

In areas where the percentage of the land in urban use is increasing, two major factors influence the amount and rate of surface run-off. These are: (1) the area in impervious cover, and (2) a change of travel time of the run-off water. Impervious areas tend to increase the volume of surface run-off from a given storm. Peak discharge may also be affected due to a change in the travel time of the run-off.

The types of management and use that are significant in influencing hydrologic conditions are the type of crops (i.e., row, small grain, or meadow); farming practices (i.e., straight-row, contour-row, or terrace-row); and the timber type and severity of use of woodlands, as indicated by age and density of the stand.

2-05. LAND USE AS A FACTOR IN WATER CONTROL

Past use of the land has resulted in water management problems in many parts of the Basin. Approximately one-half of the cropland and about one-third of the pasture in the Basin are subject to severe erosion with accelerated surface run-off. While there is serious loss from the depletion of the fertility of the soil itself, the quality of the stream water is impaired. Sediment interferes with self-purification of streams; causes increasing costs and difficulties in the treatment of water supplies; is detrimental to fish and other marine life; and causes loss of channel and reservoir storage capacity and, thus, contributes to higher flood stages.

2-06. AGRICULTURAL NEEDS FOR WATER

The agricultural needs for water in relation to land uses fall into two categories: (1) domestic purposes, livestock watering and other rural uses, and (2) irrigation.

The quantity of water used for domestic purposes depends largely on the convenience of the source of supply. About 35 gallons per day per person is used where the water is readily available. Where water must be pumped by hand, its use drops to only about 7 gallons per person per day. Thus, average annual use per rural residence would be approximately 42,000 gallons based on an average of 32 gallons of water per capita per day and average households of 3.6 persons. The estimated total annual rural residential water required in the Basin is 10,700 million gallons.

Water for livestock and agricultural uses other than irrigation amounts to 5,300 million gallons annually. The greater of the two uses is for livestock water, which amounts to 4,100 million gallons annually. "Other uses" include such items as washing dairy equipment, cooling milk, cleaning barns and poultry houses, spray-water and food processing. This figure amounts to 1,200 million gallons annually.

Although about one-half of the annual rainfall occurs during the period April through September, irrigation becomes important because the total for any one month may occur in one or two storms. Irrigation provides safeguards against droughts, helps to increase yields, permits production of higher quality products, aids in earlier maturity, and sustains forage growth during the late summer and fall.

Increased use of water for irrigation in the Basin has occurred since 1950, and principally since 1953. Total area irrigated in 1955 in the Delaware River Basin was about 43,000 acres. Of this amount, 75 percent was located in the Coastal Plain area. Irrigation is concentrated here because the soils and climate are suitable for the production of high-value truck crops and ground water is readily available at shallow depths.

Water used for irrigation in 1955 averaged 1 inch per application for four applications, a total of 14,676 acre-feet, or 4,782 million gallons.

Farmers generally follow a rule of thumb of 1 inch per week for all soils and crops. With this practice, oftentimes too much water was applied and, consequently, was lost to deep percolation when soil moisture and the growth stage of plants were not considered. At other times, the practice of applying 1 inch per week was far short of plant moisture needs, especially during drought periods of long duration where the second and third cycle of irrigation is required.

With good irrigation practice, each application of water should fill the root zone to field capacity. This suggests that, in addition to better timing, the total water application during the growing season based on effective rainfall should be at least doubled, or about 8 acre-inches. On present crops and acreages grown, this would

amount to about 30,000 acre-feet, or 9,775 million gallons.

2-07. OTHER RURAL WATER NEEDS RELATED TO LAND USES

Water is also needed in rural areas for recreational uses and for residences and industries not served by municipal systems. No attempt has been made to estimate the needs for these purposes. However, the increased interest in farm ponds; marsh development; and other installations for swimming, boating and fishing will result in significant demands on water supply. Many of these uses are non-consumptive and can be integrated into multi-purpose development.

2-08. PRESENT STATUS OF FLOOD AND SEDIMENT DAMAGE

Almost every year damaging floods occur at some point in the Basin. These floods are often local but, for the damage area, they may result in greater damage than those associated with floods of greater extent. They cause damages to growing crops; land damages from streambank erosion; deposition of infertile overwash and scour; damage to minor agricultural improvements, secondary roads and bridges, homes and stores; and create problems of maintaining stream channel capacities. Although these local floods do not individually cause damages of the magnitude of major floods, they do, in total, account for a substantial portion of the average annual flood damages.

Damages were appraised for several small watersheds. For all watersheds studied, the average annual damage was estimated to be approximately $800 per square mile. However, for the August 1955 flood, damages in several watersheds ranged from $5,000 to $12,000 per square mile of drainage area.

Sedimentation problems in the Delaware River Basin are extremely variable in extent and in the types of material deposited. Sediment deposits in the steep headwater areas are predominately coarse materials that have been deposited in large quantities where the flowing waters spread over a wider flow path, or where the channels become less steep.

Because of the shallow soils and their limited storage capacity, the streams draining the upper part of the Basin are characteristically flashy. Storms of moderate intensity may cause sharp increases in stream discharge and the high velocity flows carry large quantities of rock, gravel, silt and debris.

The sand and gravel deposits in the headwater areas and the silts and clays in the lower valley and bay are both largely products of erosion. In both instances, this results from improper use and management of land.

2-09. FUTURE CHANGES IN RURAL LAND USE AND WATER NEEDS

Early settlement usually located on or adjacent to the best agricultural

lands. These same settlements are now the centers of urban expansion. Therefore, much of the new expansion will likely occur on large areas of the most productive agricultural lands. The increase in nonagricultural uses of these lands will lead to changes in future agricultural land use and management in other parts of the Basin. Intensive agriculture will tend to retreat from advancing urban developments. This will tend to result in more intensive use of rougher topography and less productive soils.

These changes in land use will have several consequences. Improved technology will, for a time, offset loss of productive lands, but the Basin will eventually become less and less agriculturally self-sufficient. Application of improved technology will require greater quantities of water, particularly for irrigation. Water demand centers will move nearer to headwater areas. More intensive use of rough watershed lands will increase problems of adequate watershed management.

With the accelerating rates of population and industrial growth, it is probable that the Delaware River Basin will lead all other major river basins in this country in the percentage of land required for urban, industrial and related purposes, such as recreation areas and highways.

Because of basically similar physical requirements, urban development and transportation systems compete directly with agriculture for the use of level and easily worked land. Other related uses, such as expansive industrial sites, golf courses, and nonfarm rural residential sites also frequently enter the competition. On the other hand, sites sought for recreational uses usually have relatively unspoiled natural features. These are generally wooded and less desirable for farming. Studies indicate that a relatively small percentage of the present woodland area will be affected. The greatest proportion of the area converted from woodland to other uses likely will occur in the small scattered woodlots now surrounding major population centers.

An example of these changes can be found in the present trends in land use in Delaware. Indications are that by 1975 there will be relatively little farmland left north of the Chesapeake-Delaware Canal. Dairying probably will decline from present levels in New Castle County. Potato and vegetable production, together with an increase in the production of cash grains, already is moving into the concentrated dairying area around Middletown. The new center of milk production probably will move westward toward or beyond the Delaware-Maryland state line.

In 1955, 43,000 acres were irrigated in the Basin. Of this, approximately 86 percent, or 37,000 acres, was for commercial vegetable production. The remaining 6,000 acres were in general farm crops.

Major use of irrigation will probably continue to be for commercial

vegetable production. It is unlikely that total acreage in vegetable production will increase. However, market demand will encourage the use of the latest technological advances resulting in greater production per acre which will, in turn, stimulate an increase in the number of acres irrigated. This, together with improved irrigation techniques, will increase the demand for water.

By 1975, an estimated 129,000 acres will be irrigated. This will require 123,000 acre-feet, or 40,000 million gallons. This is expected to increase to 132,000 acres by 2010, requiring 41,000 million gallons; and by 2060, to 142,000 acres and 44,000 million gallons. Most of the production of irrigated truck crops will continue to be concentrated in Coastal Plain areas although a few producers will irrigate specialized crops in other parts of the Basin.

Water for future irrigation requirements from both ground and surface water can be provided if present sources of supply are developed and are not pre-empted for other uses. Small dams will be needed in some instances to impound surface water for irrigation use. Irrigation potentials from large structures on the mainstem or principal tributaries have not been considered in this report.

The question of cost and proximity to areas to be irrigated will need to be considered in order to determine how much of the potential storage can be economically utilized. Needed research, technical assistance, and education in future years should contribute to the adoption of improved techniques for the conservation and use of water. The efficiency of water application on the farm and the efficiency of storage and delivery should greatly improve as a result of advancements in technology and fuller use of conservation irrigation methods and practices now known.

Water needs for rural use other than irrigation also will change in the years ahead. Demand for water for rural residences will increase to about 100,000 gallons per household per year by 1975, as more and more of the rural residences become equipped with modern conveniences. This increase parallels the national trend in use of water; but because of rural features, it is well below the 200 gallons per person per day that has been predicted for urban-industrial areas. By 1975, rural residential users in the Basin will require an estimated 25,100 million gallons annually, and demand is expected to increase slightly by the year 2060. Also, it is estimated that by 2060, the number of rural people dependent upon private water sources will be about the same as in 1960. The increased number of total households, resulting from increased urban expansion, are expected to be served by municipal water systems. The increase in the number of city-employed rural residents dependent on private or rural water sources is expected to offset roughly the decrease in the number of farm residents.

Water needed for livestock also will increase. The number of dairy

cows is estimated to increase by about 20 percent by 2060. Most of the increases probably will occur in the central and northern areas and little significant change is indicated for the southern or Coastal Plain area. This increase in water requirements for livestock will be from the current 5,300 million gallons per year to more than 6,000 million gallons per year by 2060.

2-10. EFFECTS OF FUTURE LAND USE AND MANAGEMENT ON WATER RESOURCE PROBLEMS

Wherever proper land use and management practices have been applied significant reduction of peak flows has resulted under certain conditions. In the Delaware River Basin, assumed changes in agricultural land use and management are expected to result in improvement in hydrologic conditions that will make important reductions in local floods on the small tributary streams but lesser reductions when storms are severe enough to cause floods on the mainstems.

The temporary storage of water in the soil and in small reservoirs that helps to reduce flood peaks will also contribute to the improvement of low flows. It also serves to make more water available for use in the headwater areas above potential major impoundment sites.

Data have been prepared for each of the problem areas for the time intervals 1975, 2010, and 2060, respectively. From these data, the changes in low flows, peak flows, and annual yields have been calculated.

Comparison of present conditions to conditions which are expected to exist in the year 2060, indicates an increase of 6 percent in natural low flows in the upper part of the Basin, resulting from improved land management practices. The percentage of increase reduces from area to area moving toward the southern part of the Basin. Along the Coastal Plain, the increase is expected to be about 2 percent. The expected decrease in peak flows follows the same pattern, varying from 8 percent in the upper Basin to 2.8 percent along the Coastal Plain. The expected reduction in total annual water yield is so slight as to be insignificant.

2-11. EFFECT OF UPSTREAM STRUCTURES ON AGRICULTURE

In developing plans for watershed protection and flood prevention projects, the effects of land treatment measures on flood flows are first determined. Structural measures are included to the extent that they can be justified by the benefits that accrue to them after the estimated benefits attributed to the application of needed land treatment measures have been deducted. Water storage in the headwater areas is also needed for municipal and industrial use and for irrigation and recreation.

Structural measures for flood prevention can be justified on the basis of the reduction of damage or for more intensive use of the lands being protected. On the basis of these factors, a limited investigation indicated that out of a potential 319 sites, 65 can now be justified. Of this number, 26 are now included in work plans prepared under the provisions of the Watershed Protection and Flood Prevention Act (P. L. 566, 83rd Congress, as amended). Although these reservoirs were considered only for flood prevention, they may have additional benefits if developed for multi-purpose use. The same would be true for the remaining 251 sites which the investigations indicated are not now justified for flood prevention alone. There are many more potential sites in watersheds, each with less than a square mile of drainage area which were not studied in this survey.

2-12. AGRICULTURE'S ROLE IN THE INTEGRATED BASIN PROGRAM

More than four-fifths of the area of the Basin is in rural uses. Consequently, more than four-fifths of the annual precipitation falls on rural lands. This places farmers and other owners of rural land in an indispensable role in the management, conservation and use of the land and water resources. All three are essential to growth and expansion.

Agriculture is a relatively minor claimant for water of the Basin on a volume basis. However, agriculture's need for water is critical for rural domestic uses, livestock production and increased irrigation. The land and water resources must be managed properly so as to make best use of available water.

SECTION III - CONCLUSIONS

Improper farming practices and misuse of land have contributed to the losses of soil from erosion and to increases in floodwater damages in some sections.

Watershed management, including land treatment and structural works of improvement, is an essential element in a program of use and control of the water resources of the Basin. Because more than four-fifths of the area of the Basin is in agricultural and other extensive land uses, watershed management becomes an important factor in the prevention of further deterioration of the soil resources; in the prevention of floods in the headwater areas; and in improving the quality of water for water supplies, recreation and pollution abatement.

Although federal, state and local agencies can help, progress in soil and water conservation and proper land use is dependent upon the efforts and attitudes of the people who own or use the land.

Water resource development, to be most effective, will require the coordinated efforts of all interests and the integration of conservation

land treatment and upstream structural measures with water management measures on the mainstem and major tributaries.

Agriculture is both complementary and competitive with the urban and industrial expansion. Agricultural management of water falling on rural lands affects both quantity and quality of the water received downstream. Because of better economic opportunities for nonfarm use, productive agricultural land is being shifted to nonagricultural uses. Unless some steps are taken by local governments, this trend will continue and accelerate. If the present trend continues, agriculture will be shifted to the less productive land and, as a consequence, more water may be needed to meet production requirements.

There is need for greater recognition of the multiple-purpose uses of the natural resources as well as constructed facilities. Otherwise, the full potential of the resources will not be achieved. In the future, greater competition for land and water will require intensive management of these resources for the production of needed products and services consistent with good conservation practices.

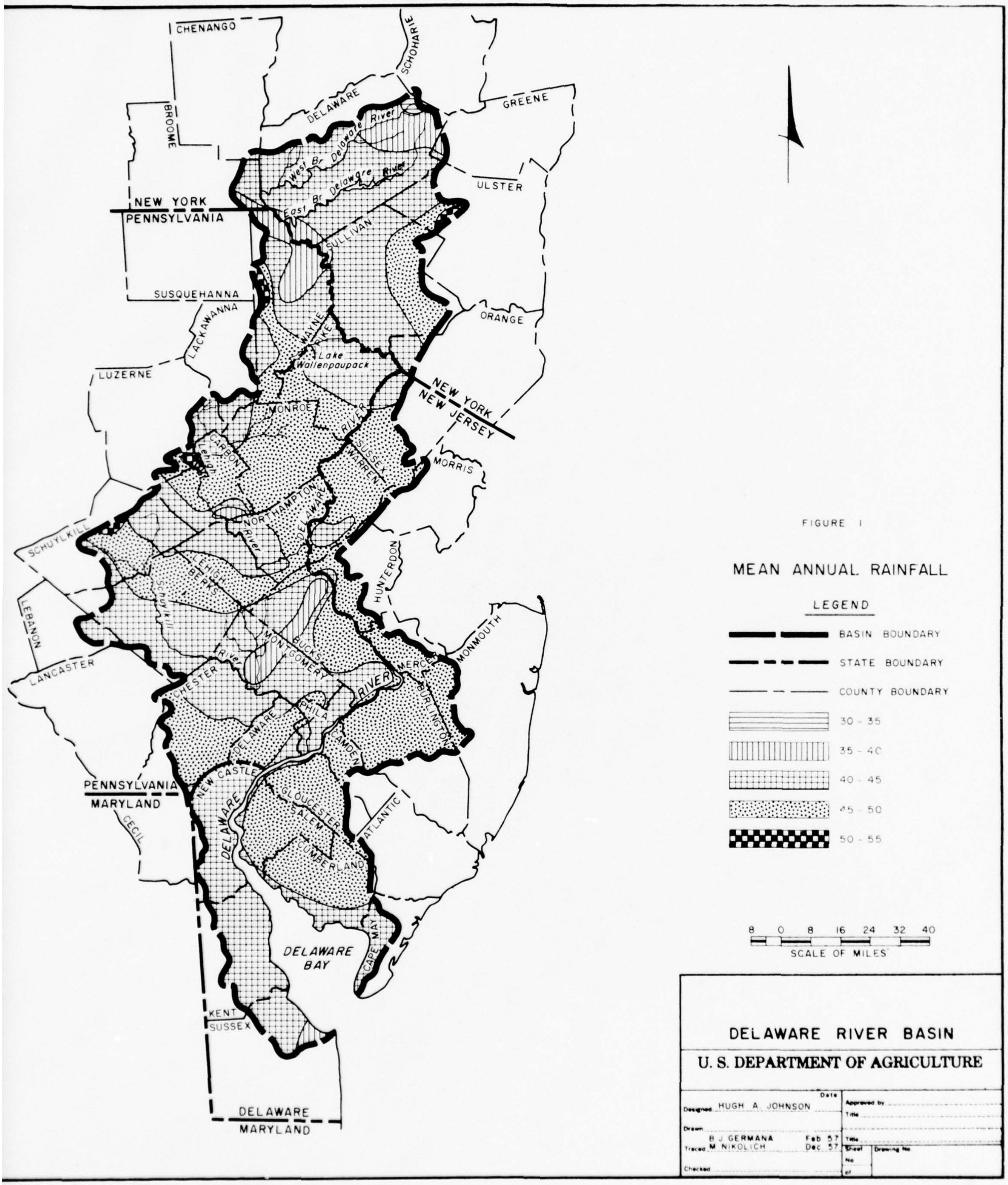

FIGURE 1

MEAN ANNUAL RAINFALL

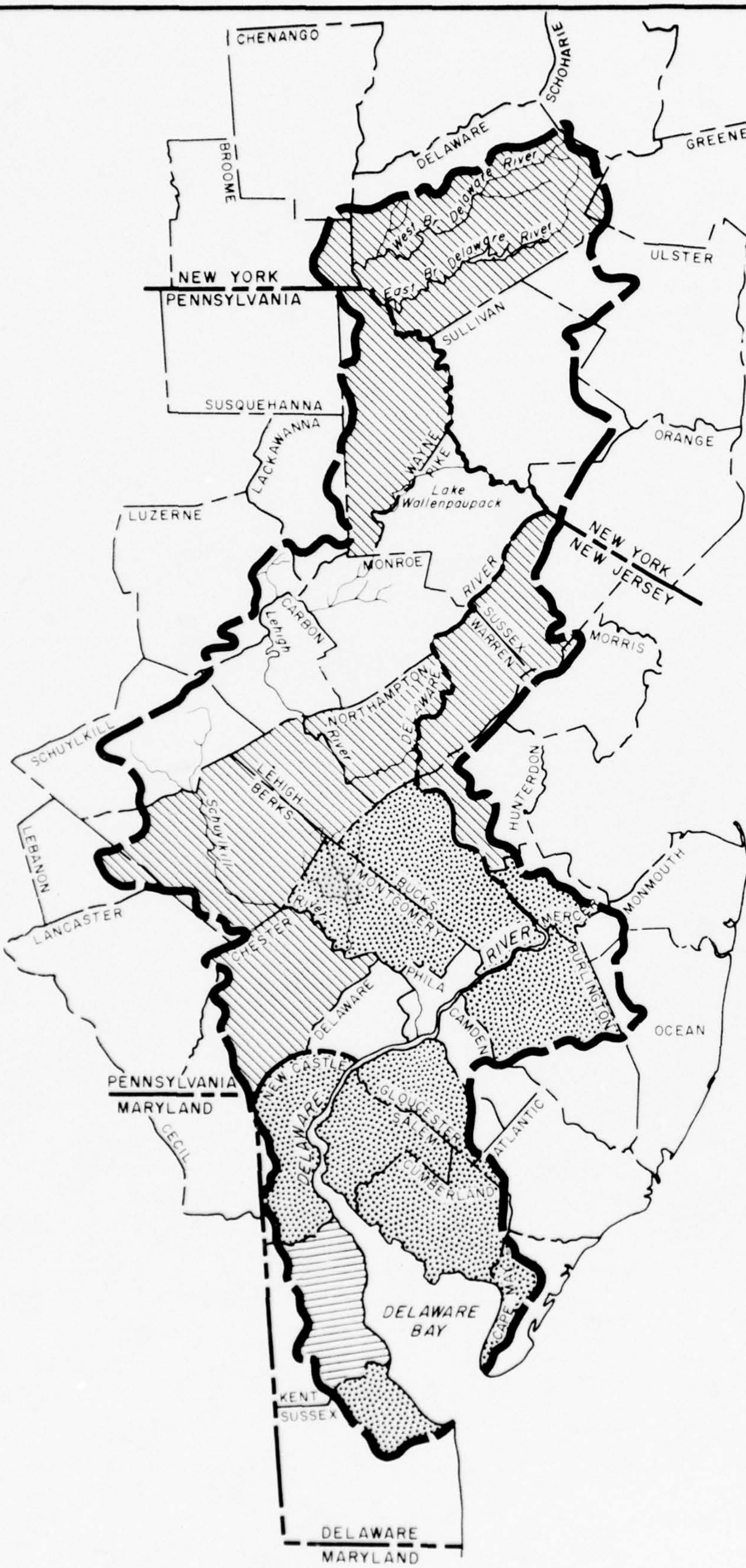

FIGURE - 2

PROPORTIONS OF LAND AREA USED FOR AGRICULTURAL PURPOSES BY COUNTIES

LEGEND

BASIN BOUNDARY

STATE BOUNDARY

COUNTY BOUNDARY

	PERCENT OF LAND USED FOR AGRICULTURE	NO. OF COUNTIES
(blank)	0 TO 30	8
(dotted)	31 TO 60	9
(hatched)	61 TO 70	10
	TOTAL	29

8 0 8 16 24 32 40

SCALE OF MILES

COMPREHENSIVE SURVEY
DELAWARE RIVER BASIN

U. S. DEPARTMENT OF AGRICULTURE

		Date	
Designed	HUGH A. JOHNSON		Approved by
			Title
Drawn	R. GERMANA	Feb 57	Title
Traced	M. NIKULICH	Dec 57	Sheet / Drawing No.
Checked			No. of

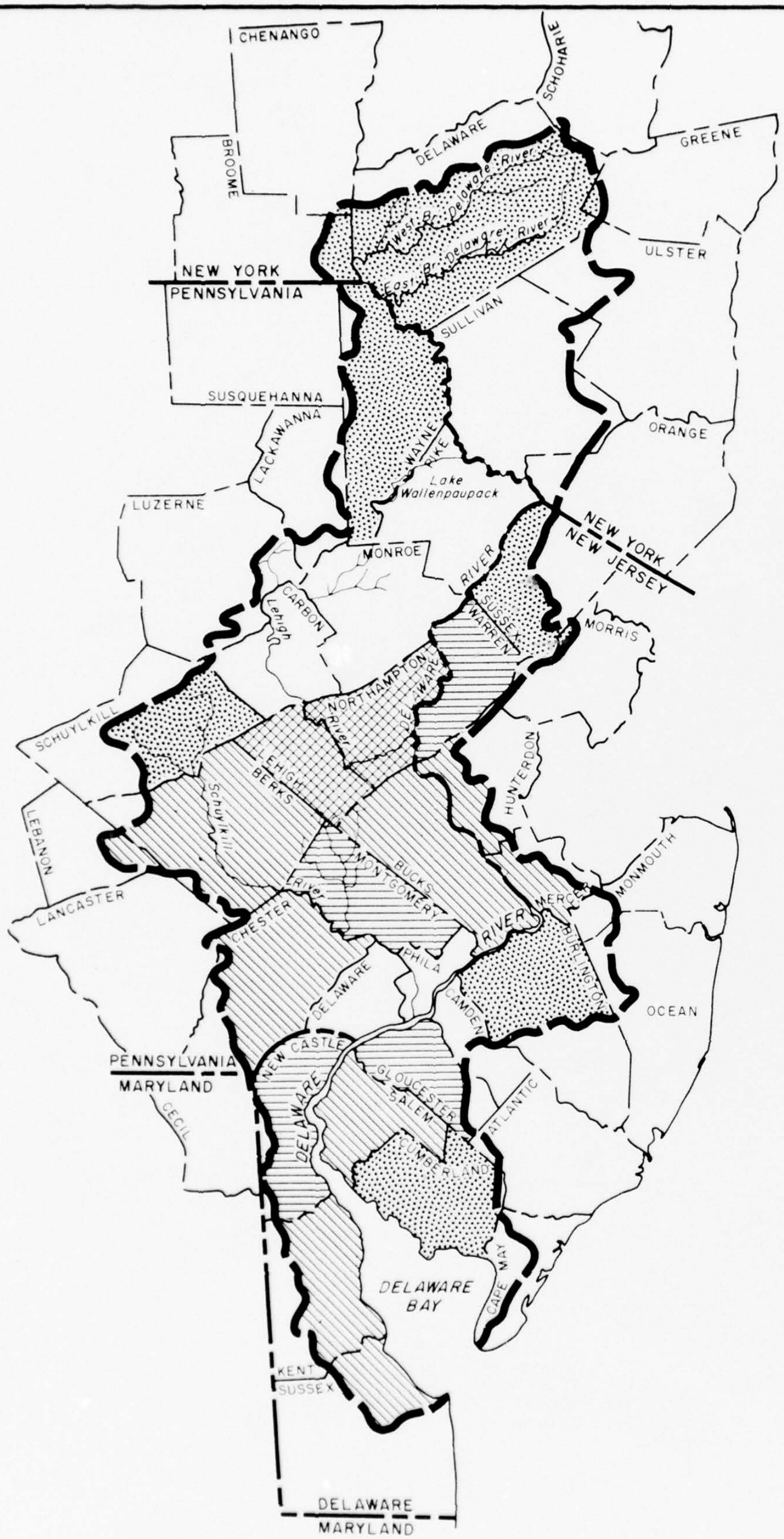

FIGURE - 3

CROPLAND HARVESTED AS A PERCENTAGE OF TOTAL LAND

LEGEND

BASIN BOUNDARY

STATE BOUNDARY

COUNTY BOUNDARY

PERCENT OF LAND USED AS CROPLAND	NO. OF COUNTIES
0 TO 10	7
11 TO 20	6
21 TO 30	9
31 TO 40	3
41 TO 45	2
	27 TOTAL

8 0 8 16 24 32 40

SCALE OF MILES

COMPREHENSIVE SURVEY
DELAWARE RIVER BASIN

U. S. DEPARTMENT OF AGRICULTURE

		Date		
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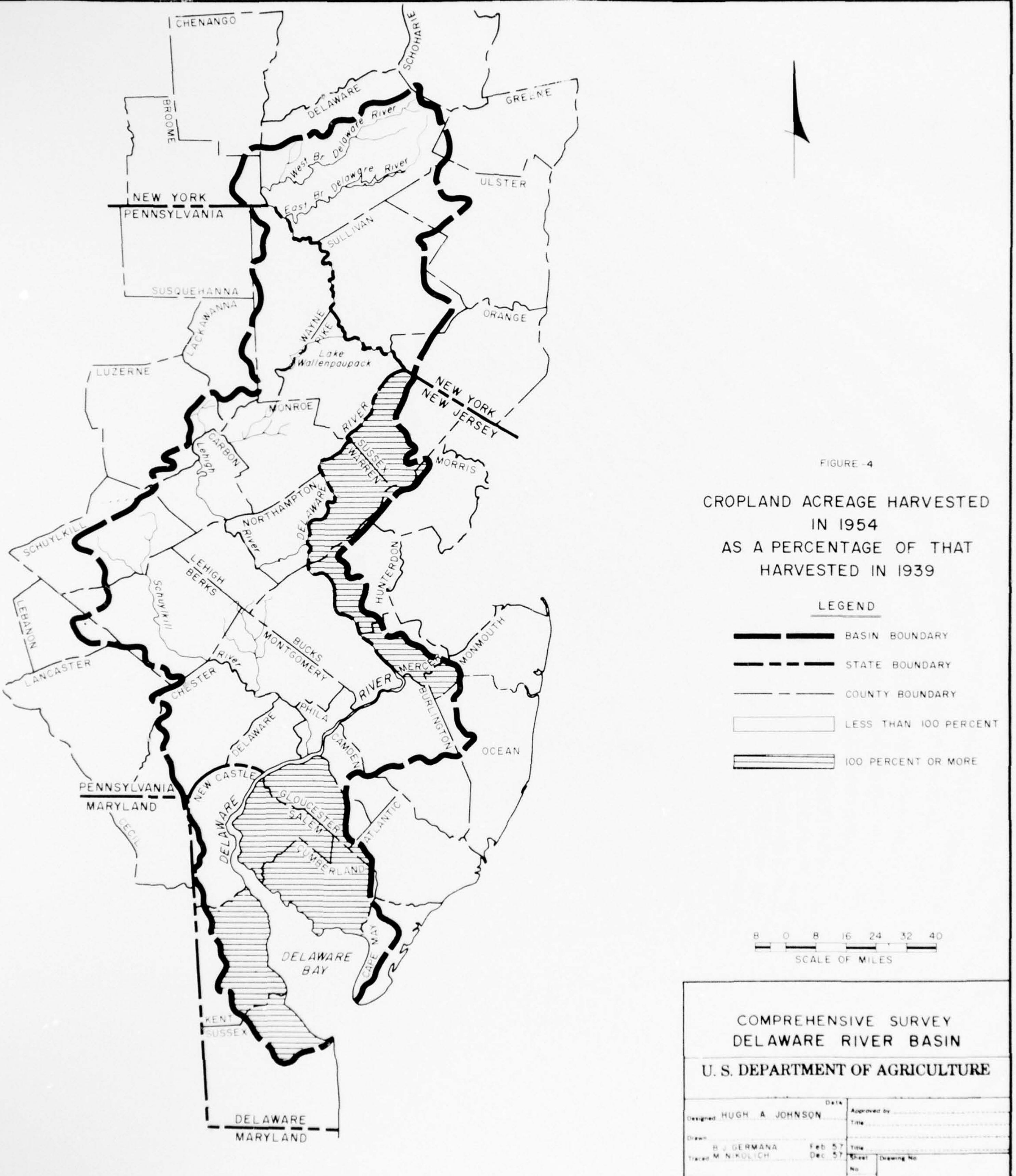

FIGURE-4

CROPLAND ACREAGE HARVESTED IN 1954 AS A PERCENTAGE OF THAT HARVESTED IN 1939

COMPREHENSIVE SURVEY
DELAWARE RIVER BASIN

U. S. DEPARTMENT OF AGRICULTURE

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Checked		

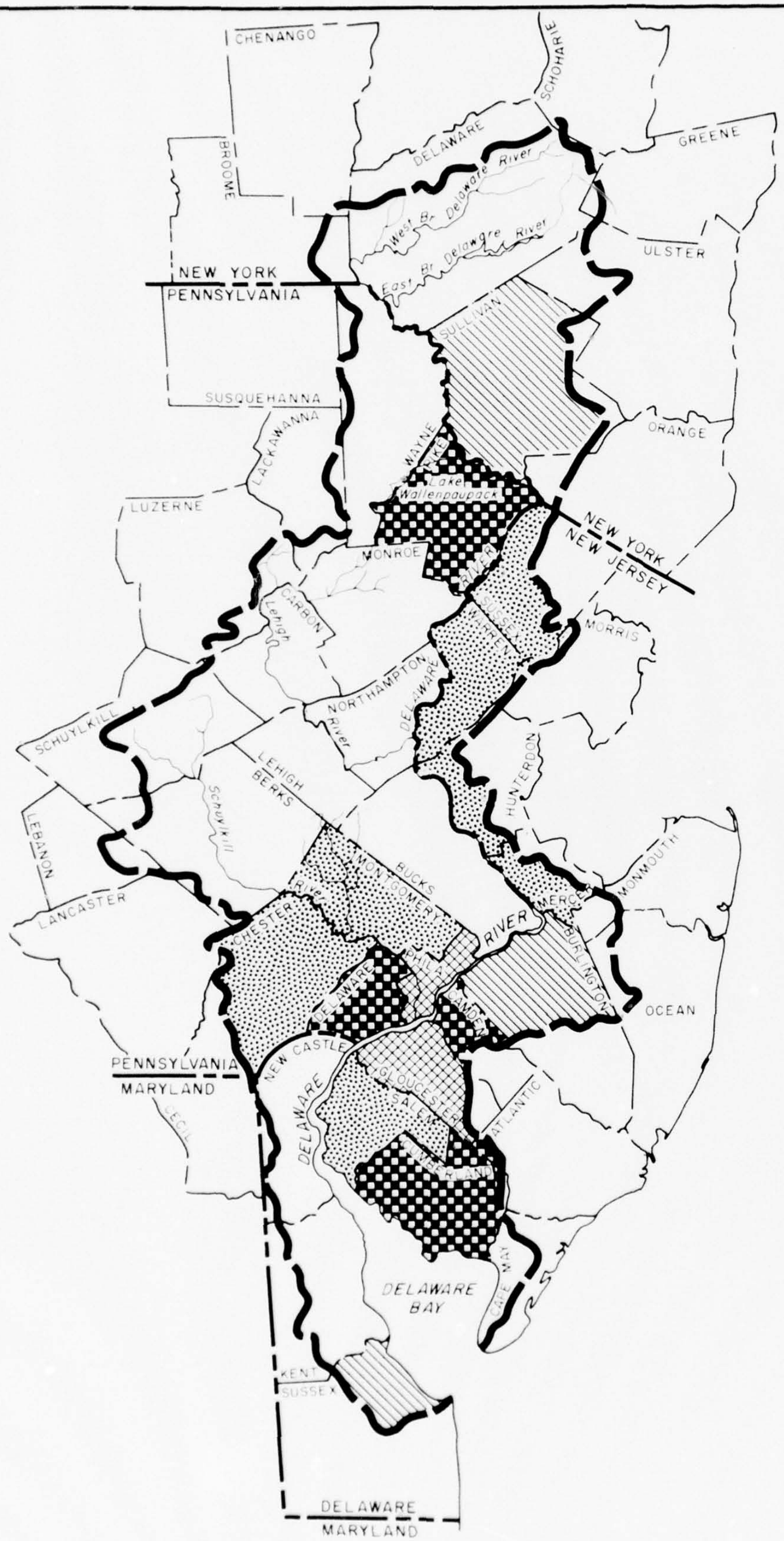

FIGURE-5

CASH FARM INCOME PER ACRE OF CROPLAND HARVESTED 1954

LEGEND

BASIN BOUNDARY

STATE BOUNDARY

COUNTY BOUNDARY

FARM INCOME PER ACRE OF CROPLAND HARVESTED	NO. OF COUNTIES
\$ 93 TO 160	11
\$ 161 TO 226	7
\$ 227 TO 292	3
\$ 293 TO 358	2
\$ 359 TO 424	4
	27 TOTAL

8 0 8 16 24 32 40

SCALE OF MILES

COMPREHENSIVE SURVEY
DELAWARE RIVER BASIN

U. S. DEPARTMENT OF AGRICULTURE

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Drawing No.

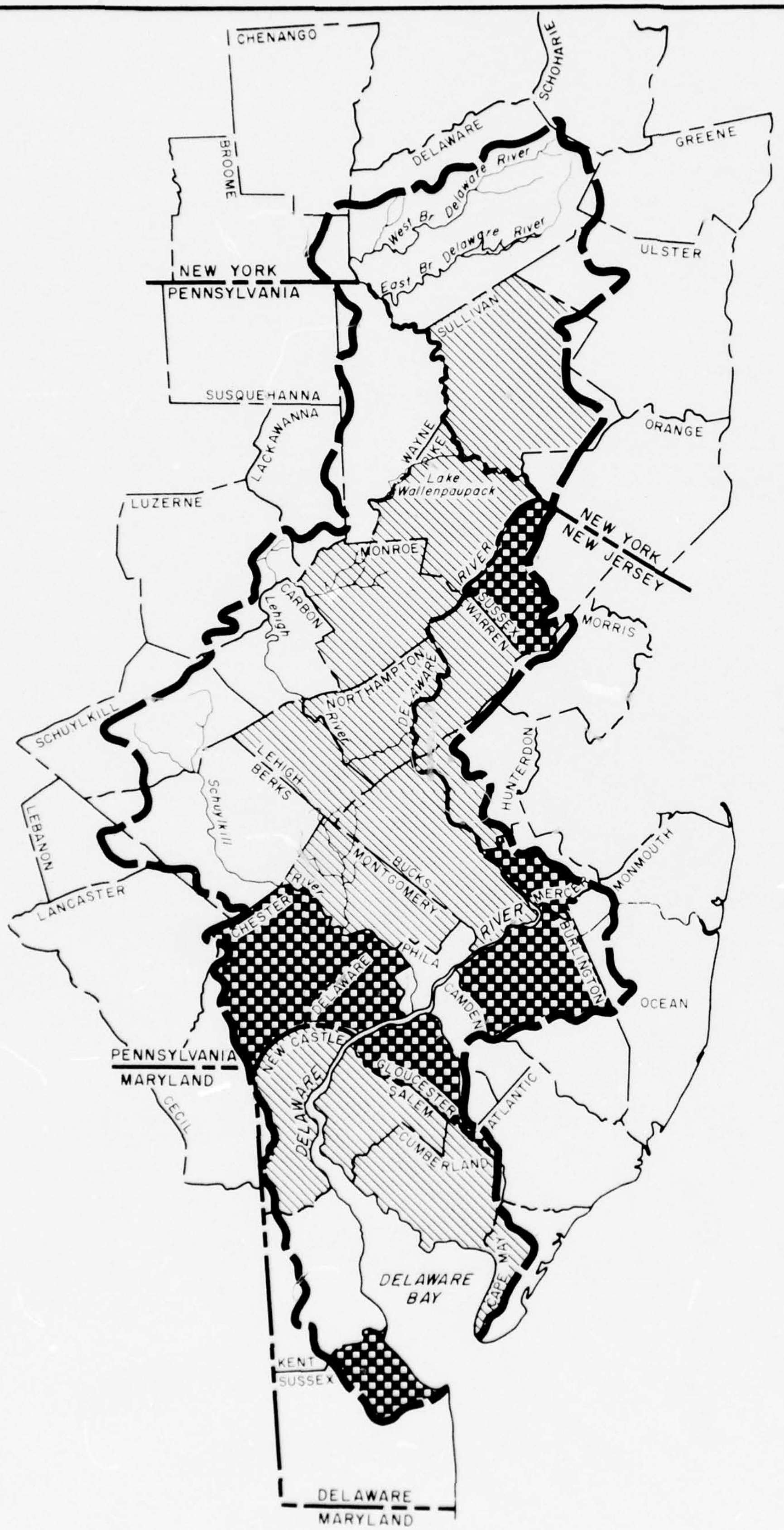

FIGURE - 6

FARM OPERATOR - FAMILY LEVEL OF LIVING INDEX BY COUNTIES, 1954

LEGEND

BASIN BOUNDARY

STATE BOUNDARY

COUNTY BOUNDARY

	1954 INDEX	NO. OF COUNTIES
(blank)	155 - 170	8
(hatched)	171 - 185	12
(checkered)	186 - 208	7
U.S. 1945	100	27 TOTAL
U.S. 1954	140	

8 0 8 16 24 32 40
SCALE OF MILES

COMPREHENSIVE SURVEY
DELAWARE RIVER BASIN

U. S. DEPARTMENT OF AGRICULTURE

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Checked			

FIGURE - 7

AVERAGE SIZE OF FARM BY COUNTIES, 1954

LEGEND

BASIN BOUNDARY

STATE BOUNDARY

COUNTY BOUNDARY

	AVERAGE SIZE OF FARMS IN ACRES	NO. OF COUNTIES
	LESS THAN 80	6
	80 TO 99	9
	100 TO 119	6
	120 OR MORE	6
	TOTAL	27

8 0 8 16 24 32 40

SCALE OF MILES

COMPREHENSIVE SURVEY
DELAWARE RIVER BASIN

U. S. DEPARTMENT OF AGRICULTURE

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Checked		

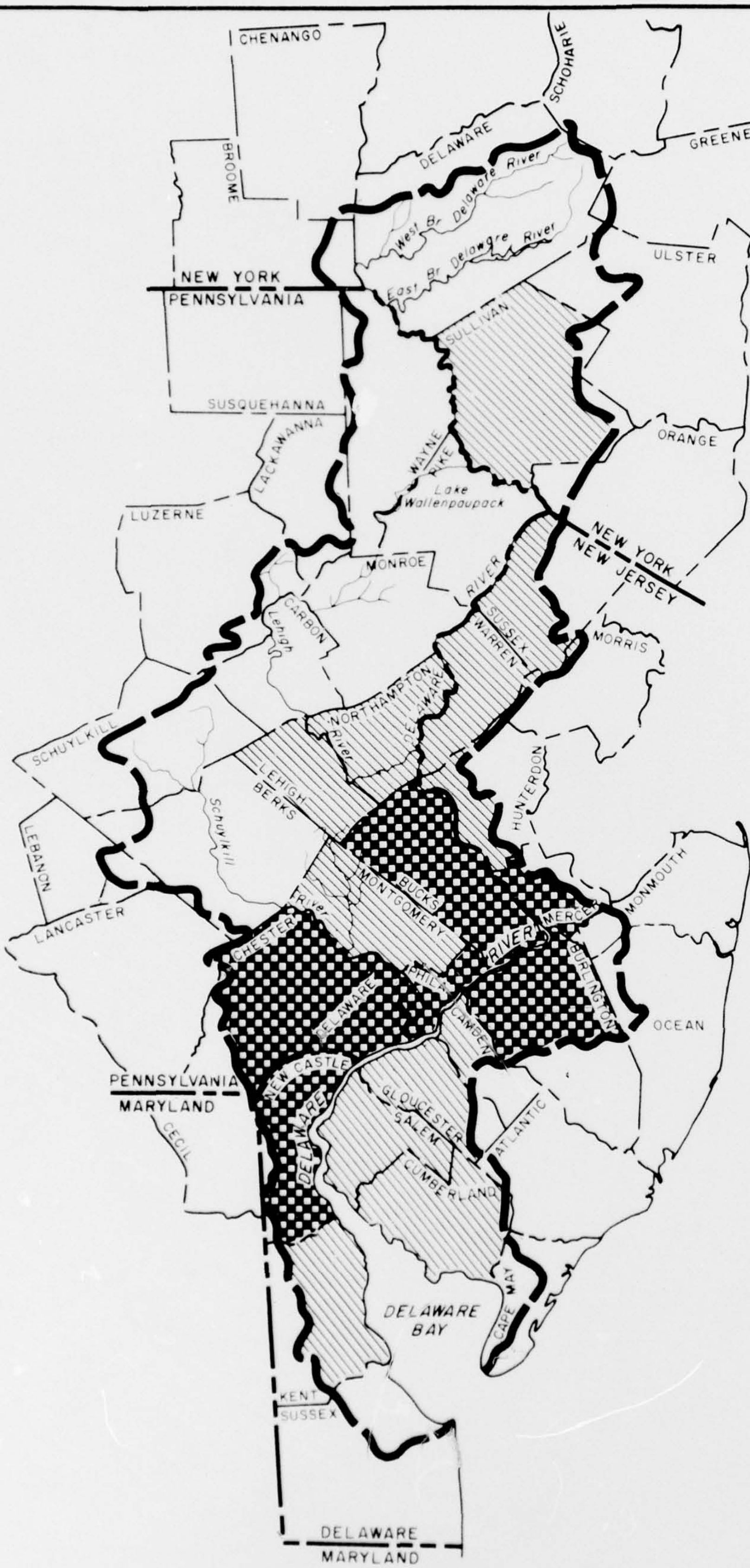

FIGURE - 8

AVERAGE VALUE
OF LAND AND BUILDINGS
IN DOLLARS PER FARM
BY COUNTIES, 1954

LEGEND

BASIN BOUNDARY
STATE BOUNDARY
COUNTY BOUNDARY
LESS THAN $16,000
$16,000 TO $31,000
$32,000 OR MORE

8 0 8 16 24 32 40
SCALE OF MILES

COMPREHENSIVE SURVEY
DELAWARE RIVER BASIN

U. S. DEPARTMENT OF AGRICULTURE

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Checked		Sheet No. of / Drawing No.

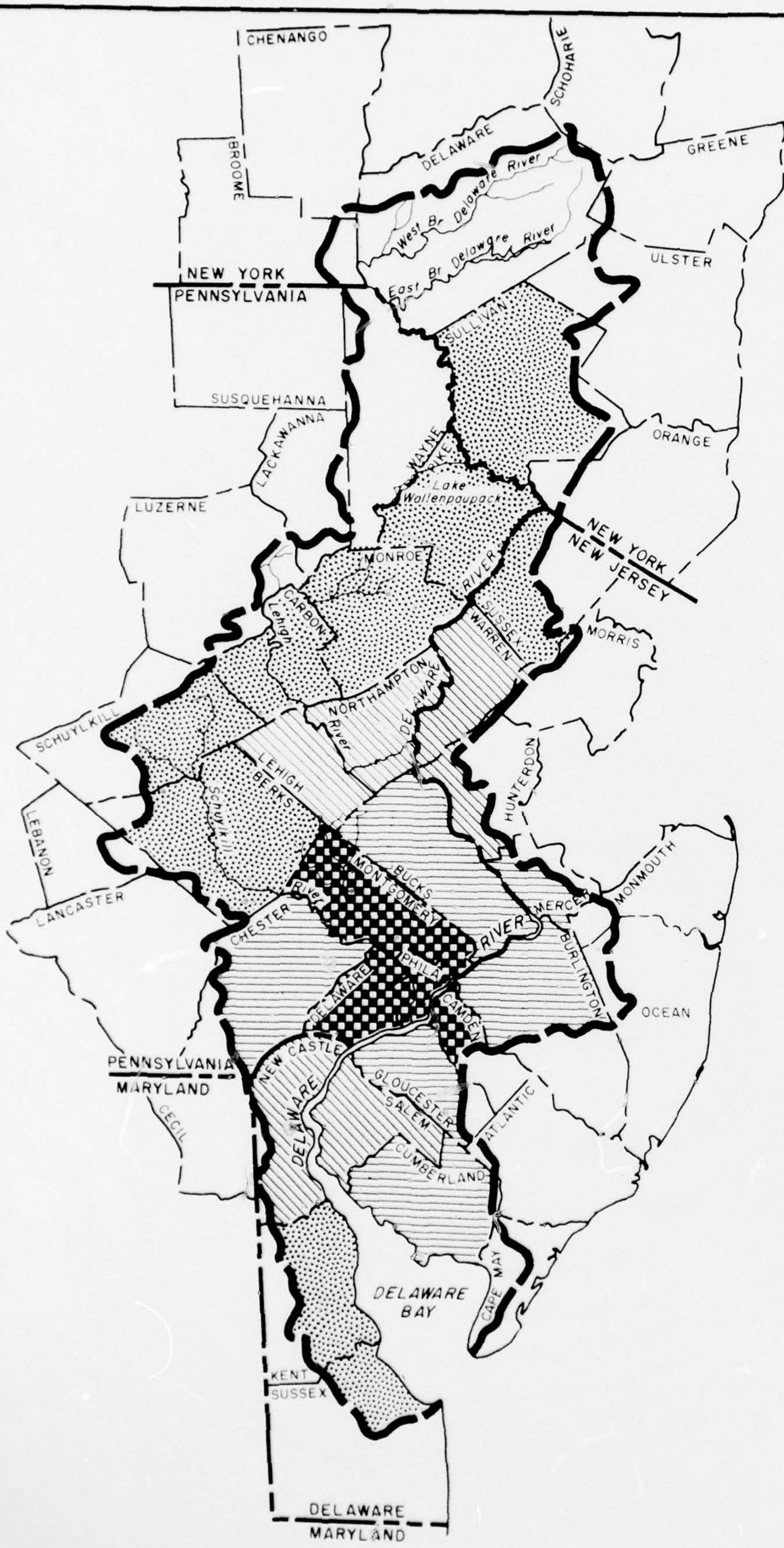


FIGURE - 9

AVERAGE VALUE OF LAND AND BUILDINGS PER ACRE BY COUNTIES

LEGEND

BASIN BOUNDARY

STATE BOUNDARY

COUNTY BOUNDARY

AVERAGE VALUE OF LAND AND BUILDINGS PER ACRE	NO. OF COUNTIES
LESS THAN $ 100	2
$ 100 TO 199	9
$ 200 TO 299	6
$ 300 TO 499	6
$ 500 AND OVER	4
	27 TOTAL

8 0 8 16 24 32 40

SCALE OF MILES

COMPREHENSIVE SURVEY
DELAWARE RIVER BASIN

U. S. DEPARTMENT OF AGRICULTURE

Designed HUGH A. JOHNSON	Date	Approved by
Drawn B. J. GERMANA	Feb 57	Title
Traced M. NIKOLICH	Dec 57	Sheet No. of / Drawing No.
Checked		

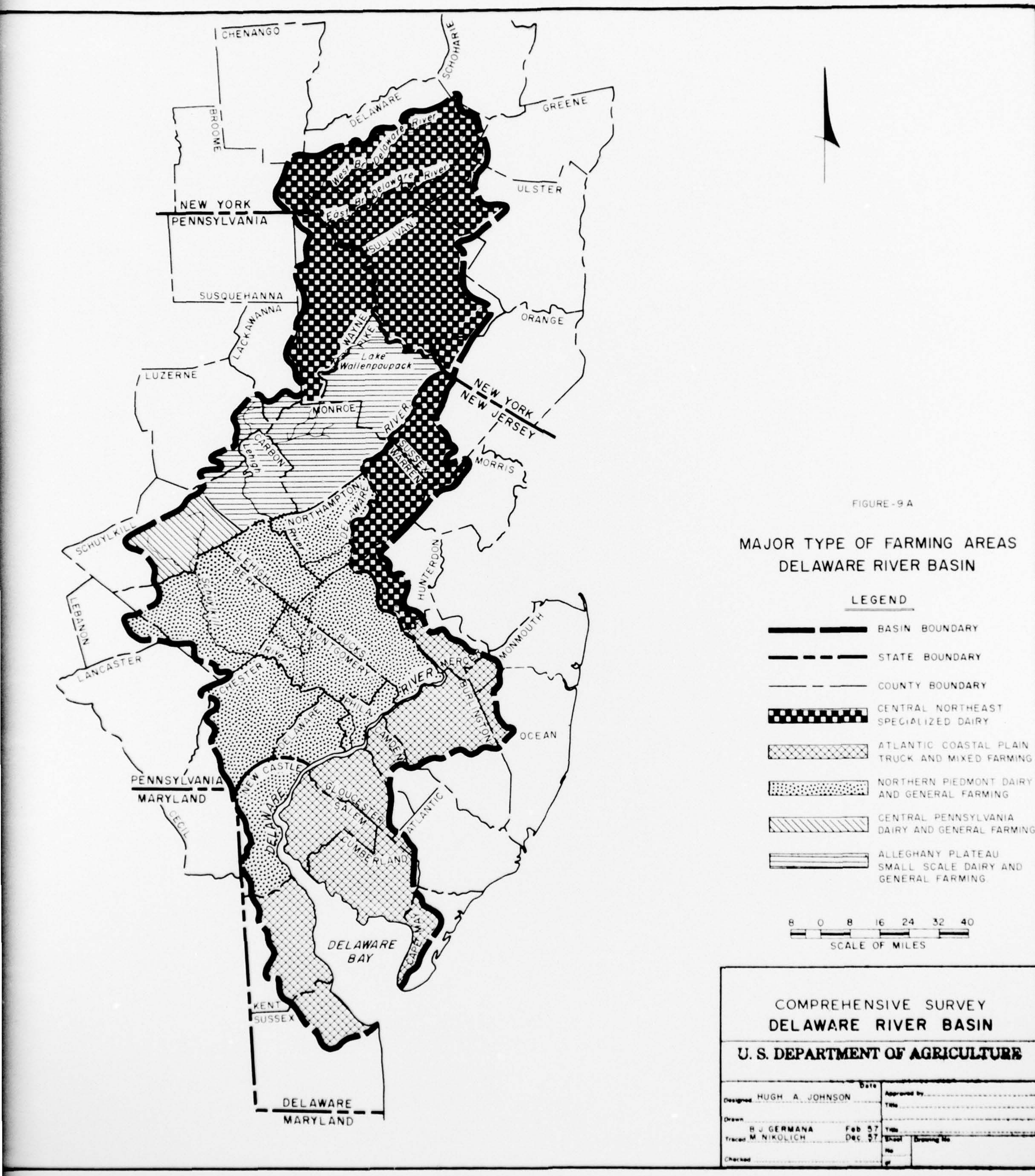
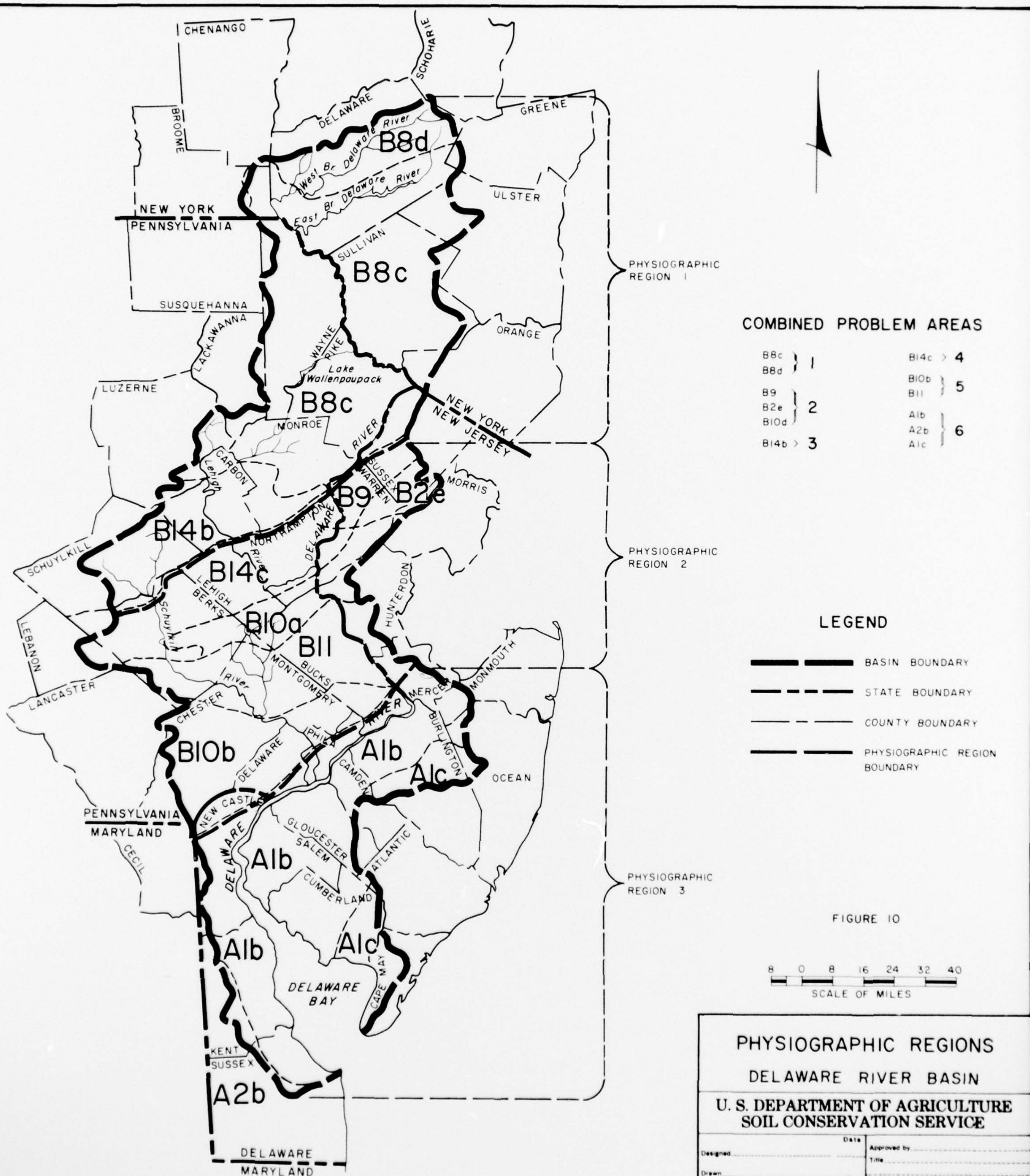


FIGURE-9 A
MAJOR TYPE OF FARMING AREAS
DELAWARE RIVER BASIN
LEGEND
BASIN BOUNDARY
STATE BOUNDARY
COUNTY BOUNDARY
CENTRAL NORTHEAST SPECIALIZED DAIRY
ATLANTIC COASTAL PLAIN TRUCK AND MIXED FARMING
NORTHERN PIEDMONT DAIRY AND GENERAL FARMING
CENTRAL PENNSYLVANIA DAIRY AND GENERAL FARMING
ALLEGHANY PLATEAU SMALL SCALE DAIRY AND GENERAL FARMING
8 0 8 16 24 32 40
SCALE OF MILES
COMPREHENSIVE SURVEY
DELAWARE RIVER BASIN
U. S. DEPARTMENT OF AGRICULTURE
Designed HUGH A. JOHNSON
Drawn B J GERMANA Feb 57
Traced M NIKOLICH Dec 57
Checked
Approved by
Title
Sheet No.
Drawing No.
CHENANGO
BROOME
DELAWARE
SCHOHARIE
GREENE
ULSTER
West Br. Delaware River
East Br. Delaware River
NEW YORK
PENNSYLVANIA
SULLIVAN
SUSQUEHANNA
LACKAWANNA
WAYNE
PIKE
ORANGE
Lake Wallenpaupack
LUZERNE
MONROE
RIVER
NEW YORK
NEW JERSEY
CARBON
Lehigh
SUSSEX
WARREN
MORRIS
NORTHAMPTON
DELAWARE
SCHUYLKILL
LEHIGH
BERKS
HUNTERDON
LEBANON
MONTGOMERY
BUCKS
MONMOUTH
LANCASTER
CHESTER
MERCER
RIVER
PHILA
BURLINGTON
DELAWARE
CAMDEN
OCEAN
PENNSYLVANIA
MARYLAND
NEW CASTLE
GLOUCESTER
SALEM
ATLANTIC
CECIL
DELAWARE
CUMBERLAND
DELAWARE BAY
CAPE MAY
KENT
SUSSEX
DELAWARE
MARYLAND



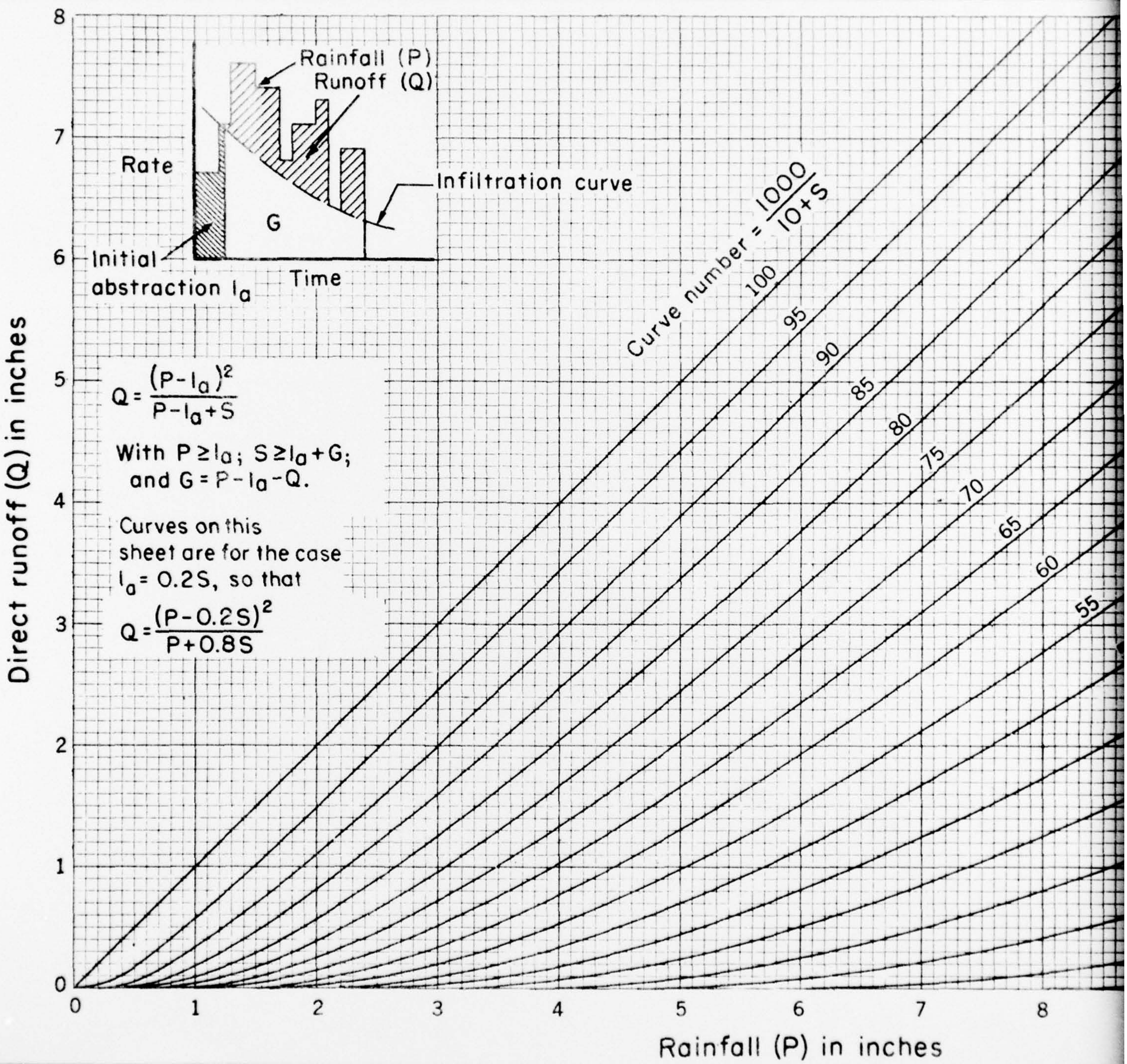
PHYSIOGRAPHIC REGIONS

DELAWARE RIVER BASIN

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

Designed	Date	Approved by	
Drawn C. B. FORD	Feb '60	Title	
Traced		Title	
Checked		Sheet No. of	Drawing No.

HYDROLOGY: SOLUTION OF RUNOFF EQUATION $Q = \frac{(P-0.2S)^2}{P+0.8S}$



REFERENCE

Mockus, Victor; Estimating direct runoff amounts from storm rainfall: Central Technical Unit, October 1955.

U. S. DEPA
SOIL CON
ENGINEERING DI

UNOFF EQUATION $Q = \frac{(P-0.2S)^2}{P+0.8S}$

P = 0 to 12 inches
Q = 0 to 8 inches

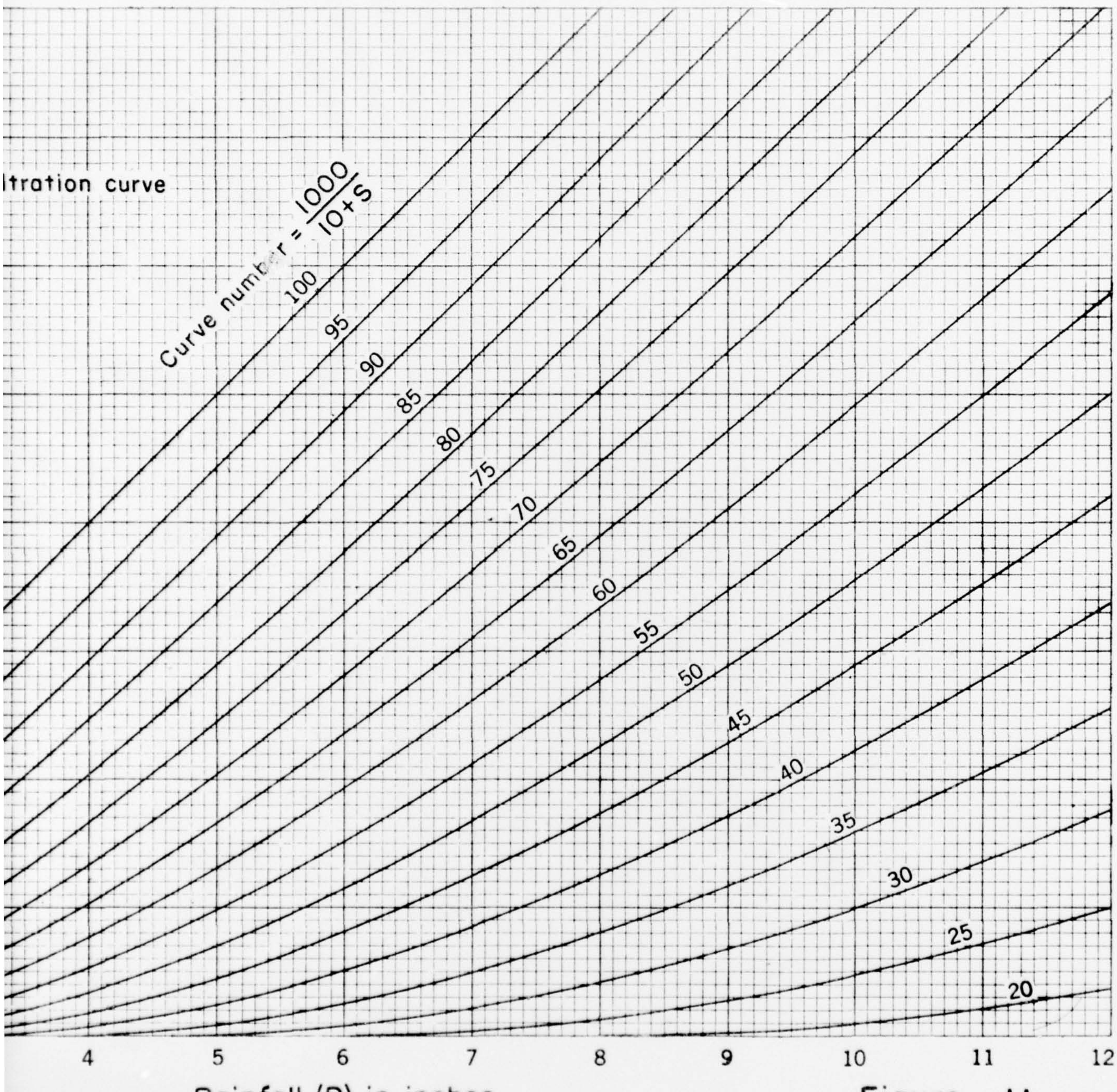


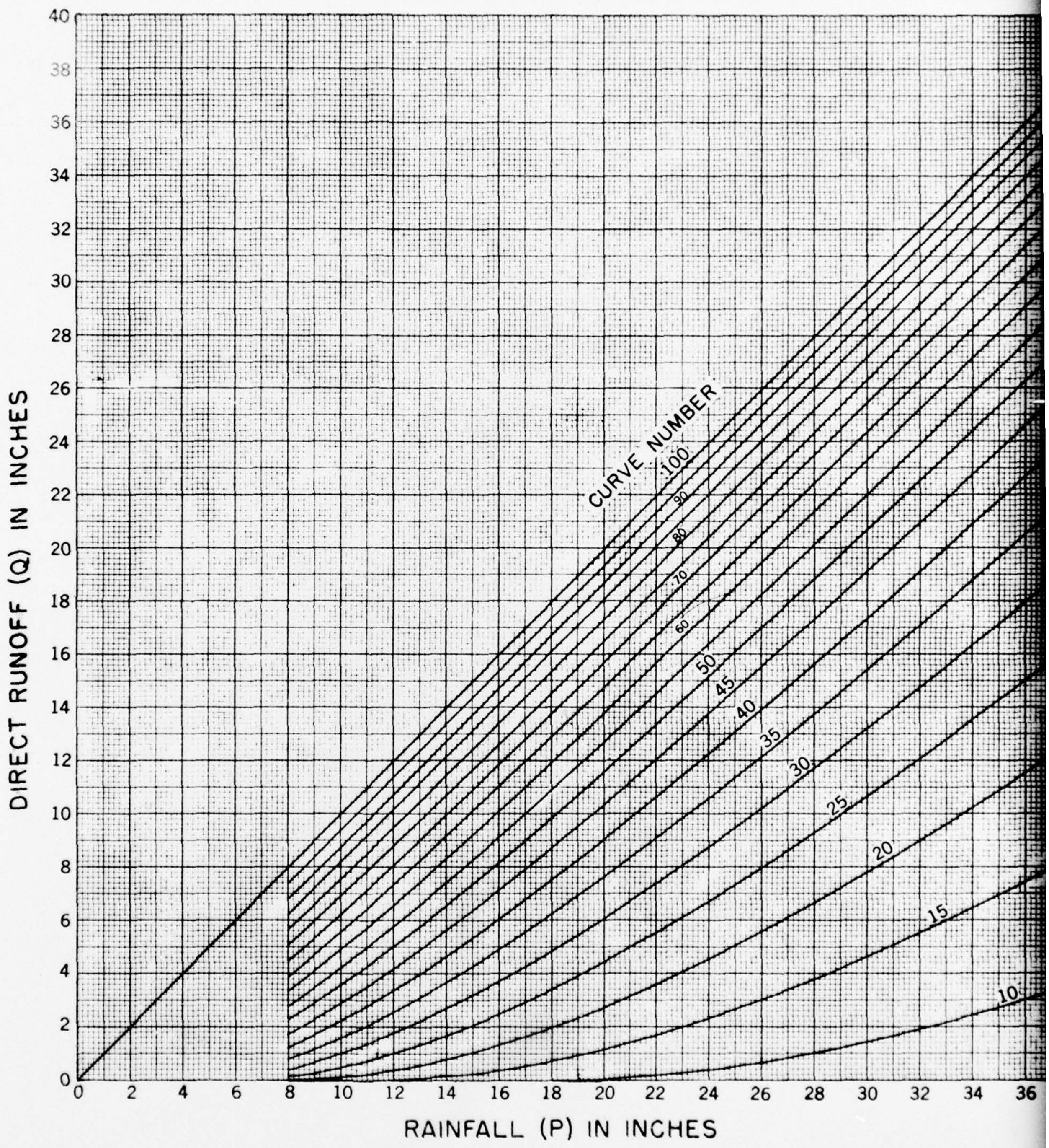
Figure 11

ounts from
er 1955.

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE
ENGINEERING DIVISION - CENTRAL TECHNICAL UNIT

STANDARD DWG. NO.
ES-1001
SHEET OF
DATE 6-29-56

HYDROLOGY: SOLUTION OF RUNOFF EQUATION $Q = \frac{(P-0.2S)^2}{P+0.8S}$



REFERENCE

Mockus, Victor; Estimating direct runoff amounts from storm rainfall: Central Technical Unit, October 1955.

U. S. DEPA[...]
SOIL CON[...]

ENGINEERING DIV[...]

EQUATION $Q = \frac{(P-0.2S)^2}{P+0.8S}$

P = 8 to 40 inches
Q = 0. to 40 inches

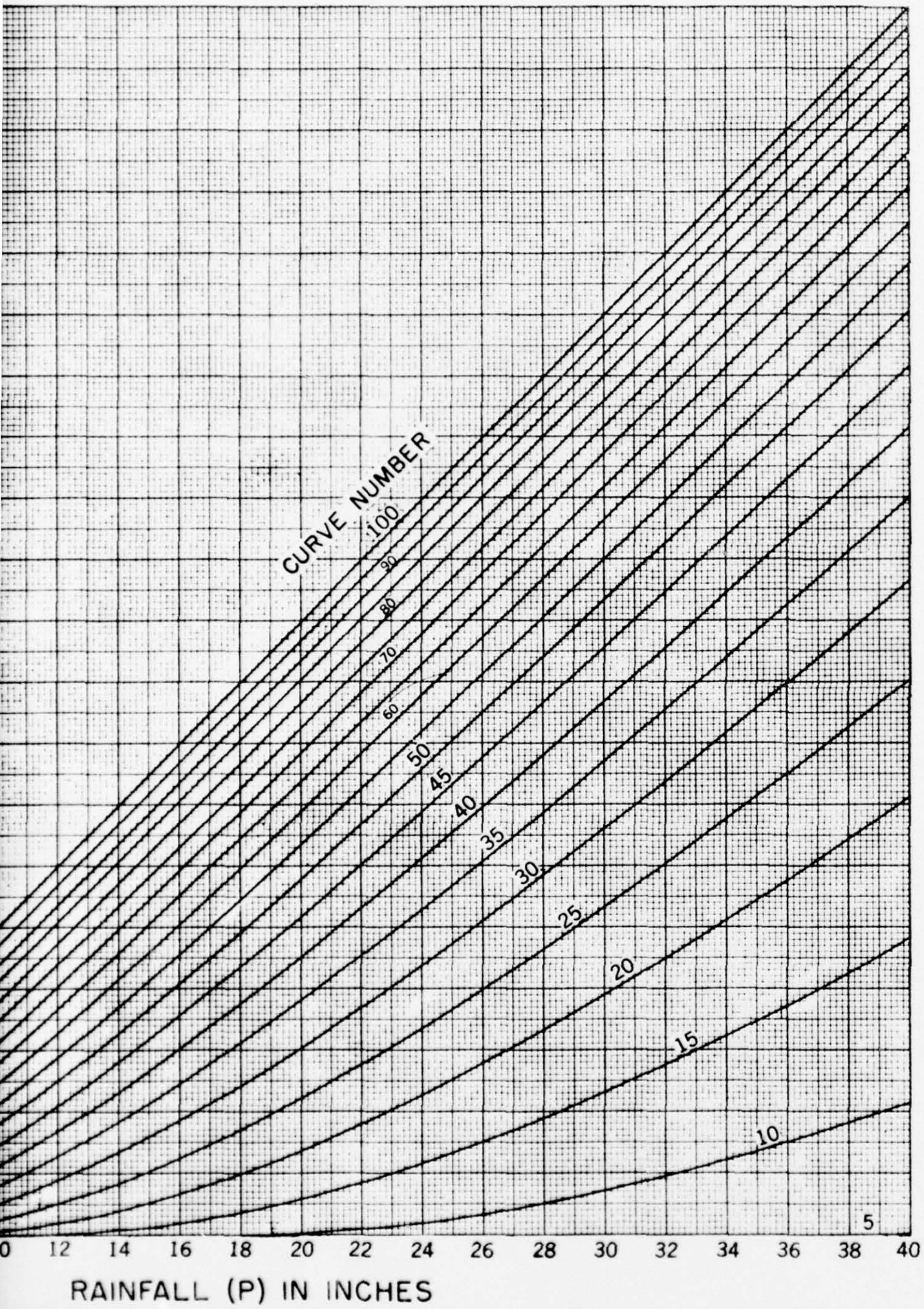


Figure II
(2 of 2)

U. S. DEPARTMENT OF AGRICULTURE SOIL CONSERVATION SERVICE ENGINEERING DIVISION - CENTRAL TECHNICAL UNIT	STANDARD DWG. NO. ES-1001 SHEET 2 OF 2 DATE 6-27-56

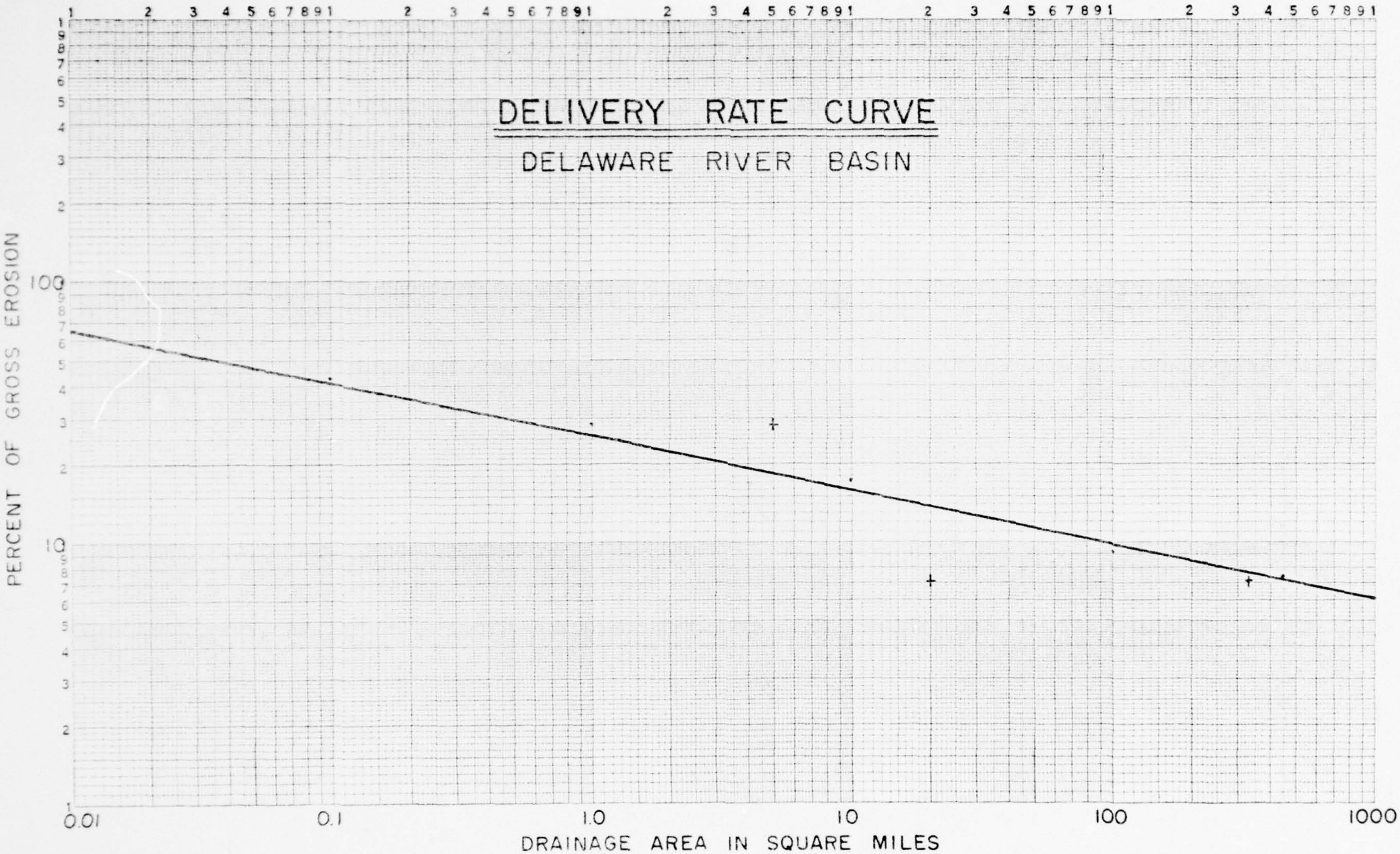


FIGURE 12

Adopted from a curve developed by John Rohel
S.C.S. Spartanburg S.C. (Unpublished)

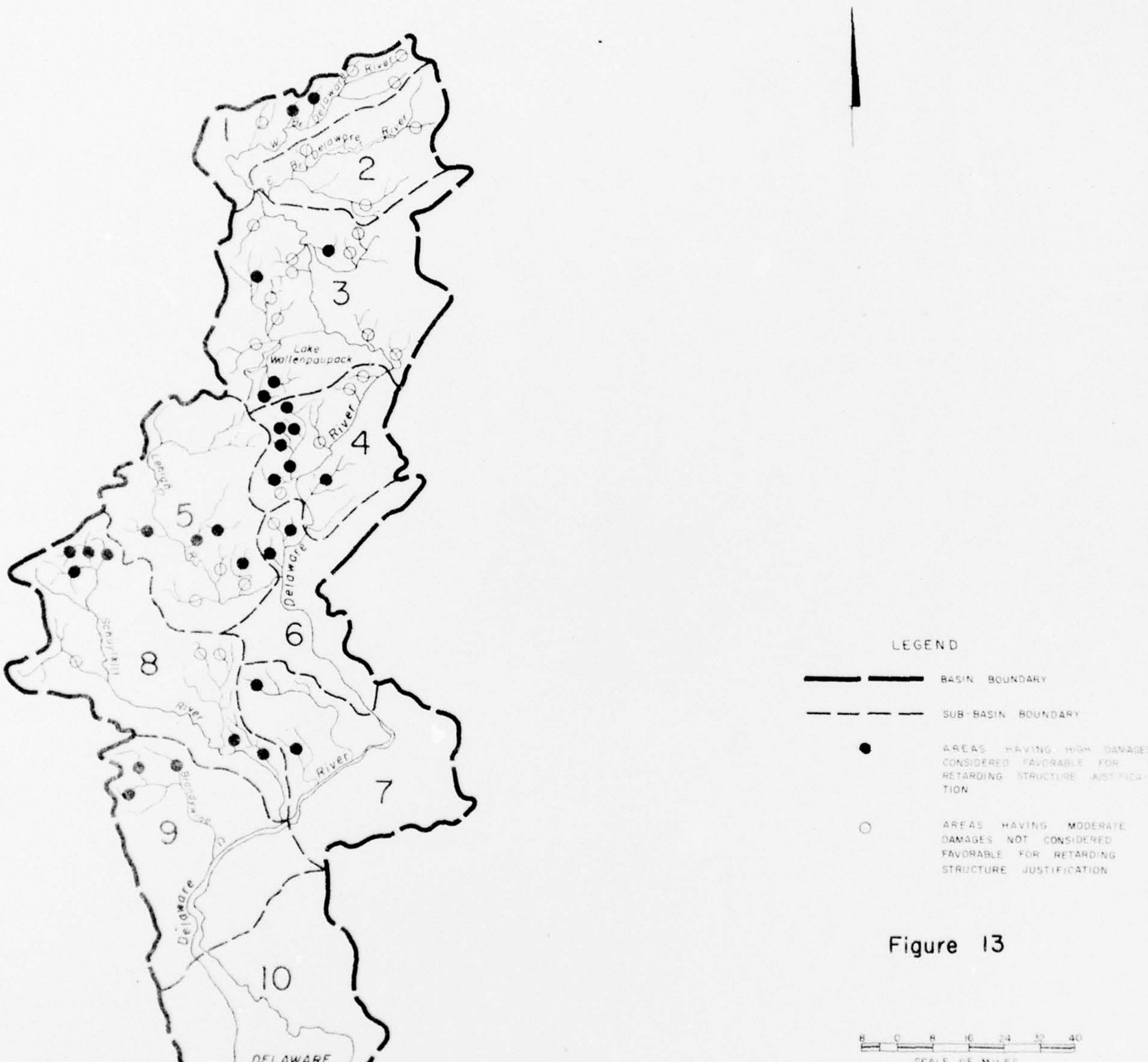


Figure 13

LOCATION OF DAMAGE AREAS

DELAWARE RIVER BASIN

U.S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

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Drawn		Title	
Traced B. J. G.	7-59	Title	
Checked		Sheet No. of	Drawing No.

Form SCS-313 (November 1955)

RUN-OFF CHANGES FOR 1.0 POINT CHANGE IN INDEX NUMBERS

(NOTE: CHANGES THAT ARE GREATER OR SMALLER THAN 1.0 POINT ARE IN DIRECT RATIO TO VALUES ON THIS CURVE)

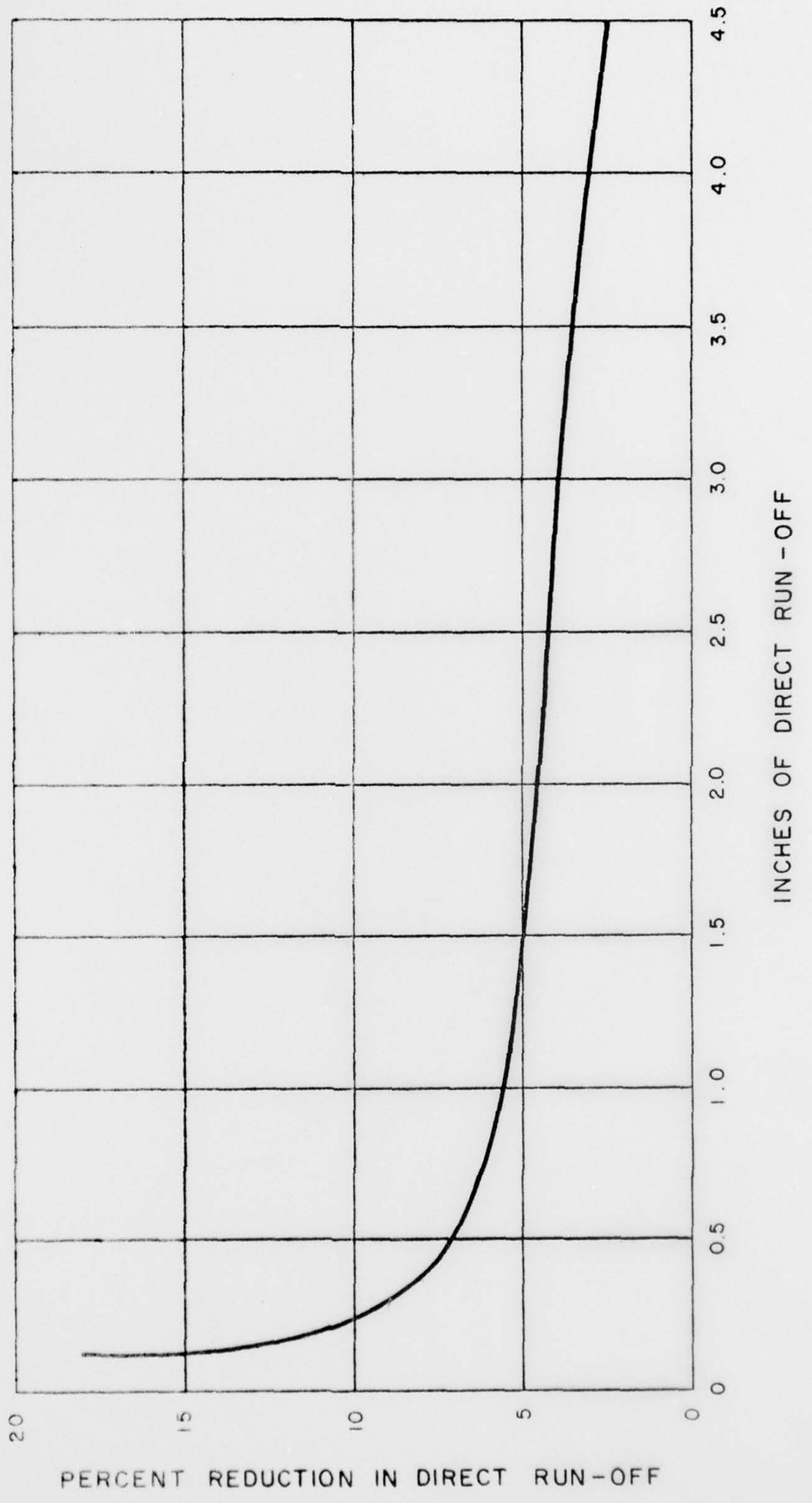

Figure 14

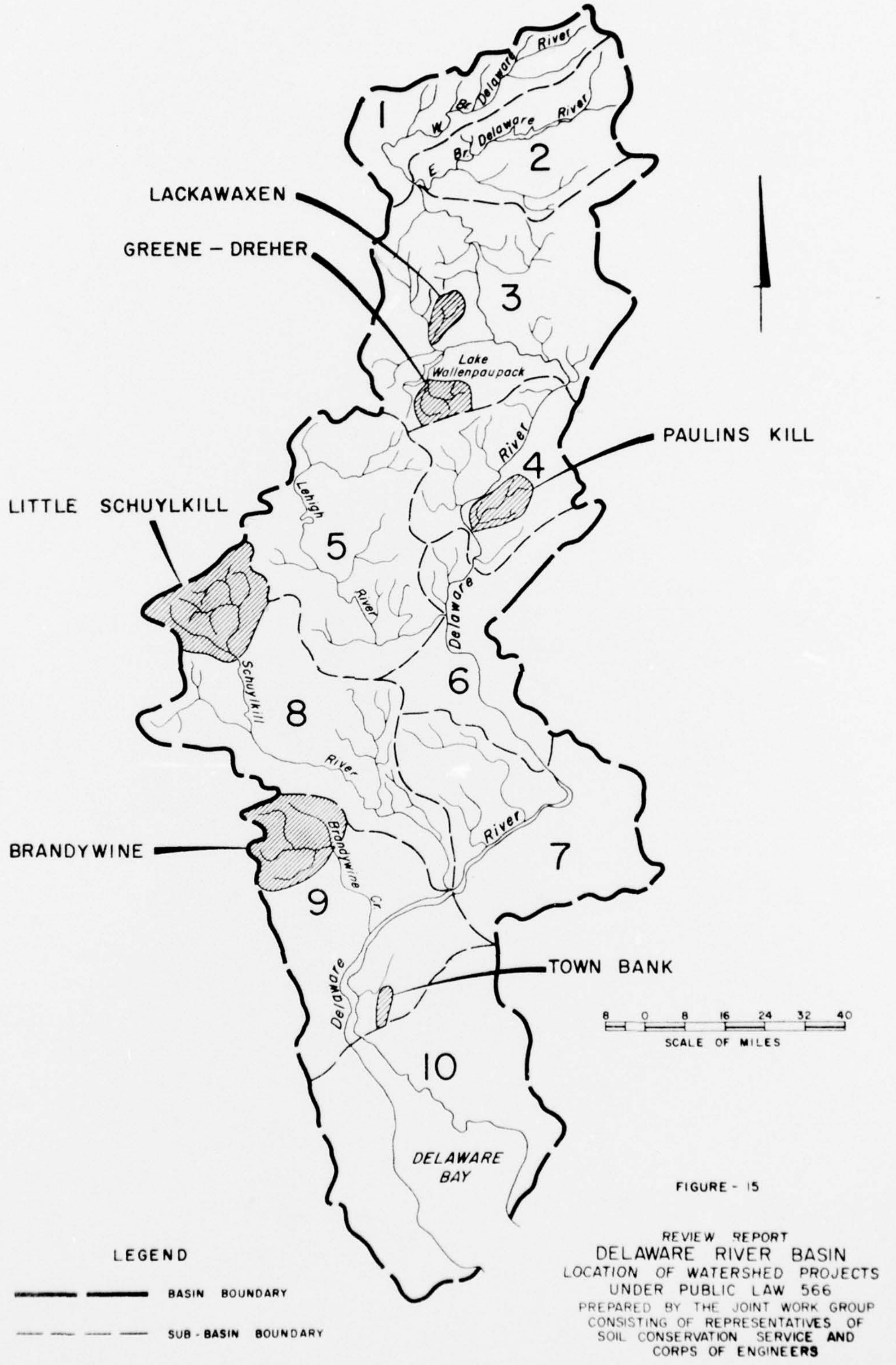

FIGURE - 15

REVIEW REPORT
DELAWARE RIVER BASIN
LOCATION OF WATERSHED PROJECTS
UNDER PUBLIC LAW 566
PREPARED BY THE JOINT WORK GROUP
CONSISTING OF REPRESENTATIVES OF
SOIL CONSERVATION SERVICE AND
CORPS OF ENGINEERS

SCHEMATIC HYDROGRAPH OF STORM RUN-OFF COMING INTO AND LEAVING A FLOODWATER RETARDING STRUCTURE

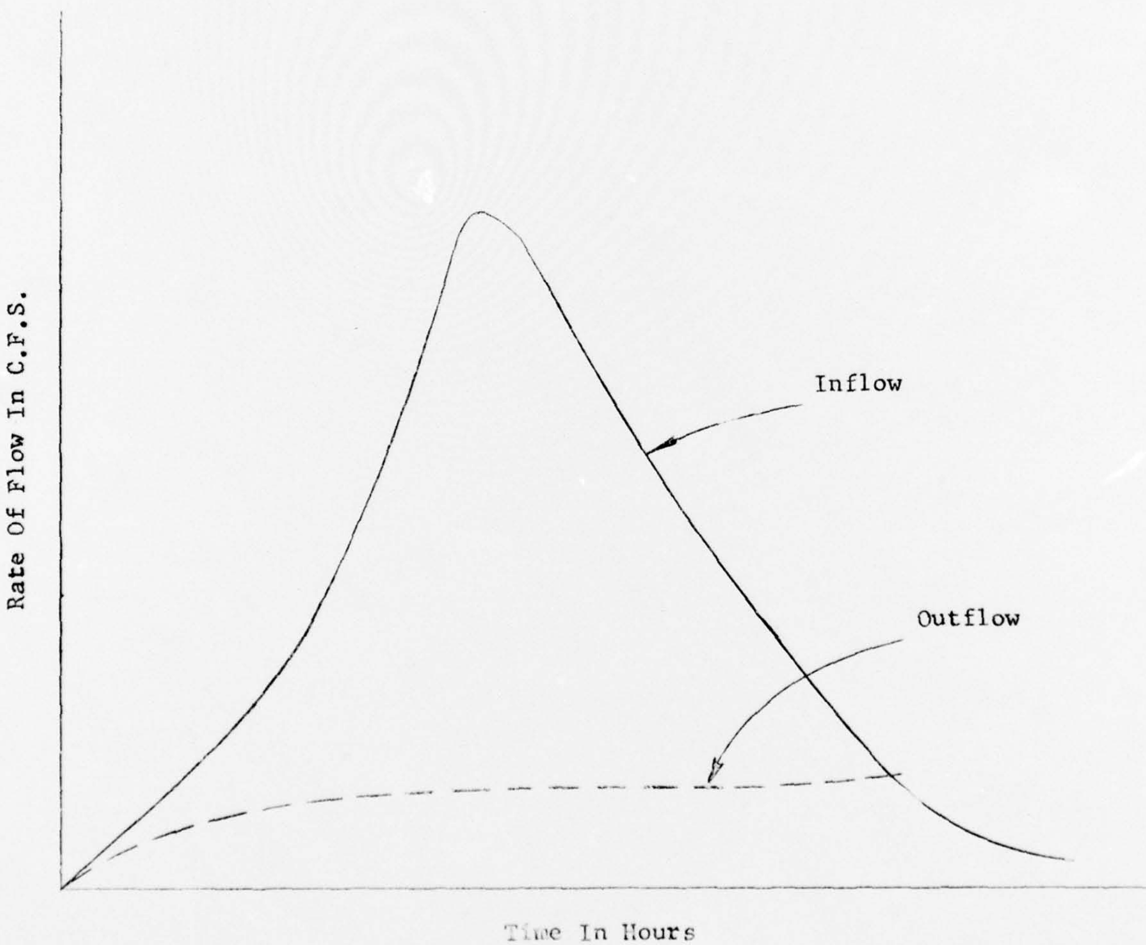

FIGURE 16

TYPICAL HYDROGRAPH AT A DAMAGE POINT
BEFORE AND AFTER THE INSTALLATION OF STRUCTURES

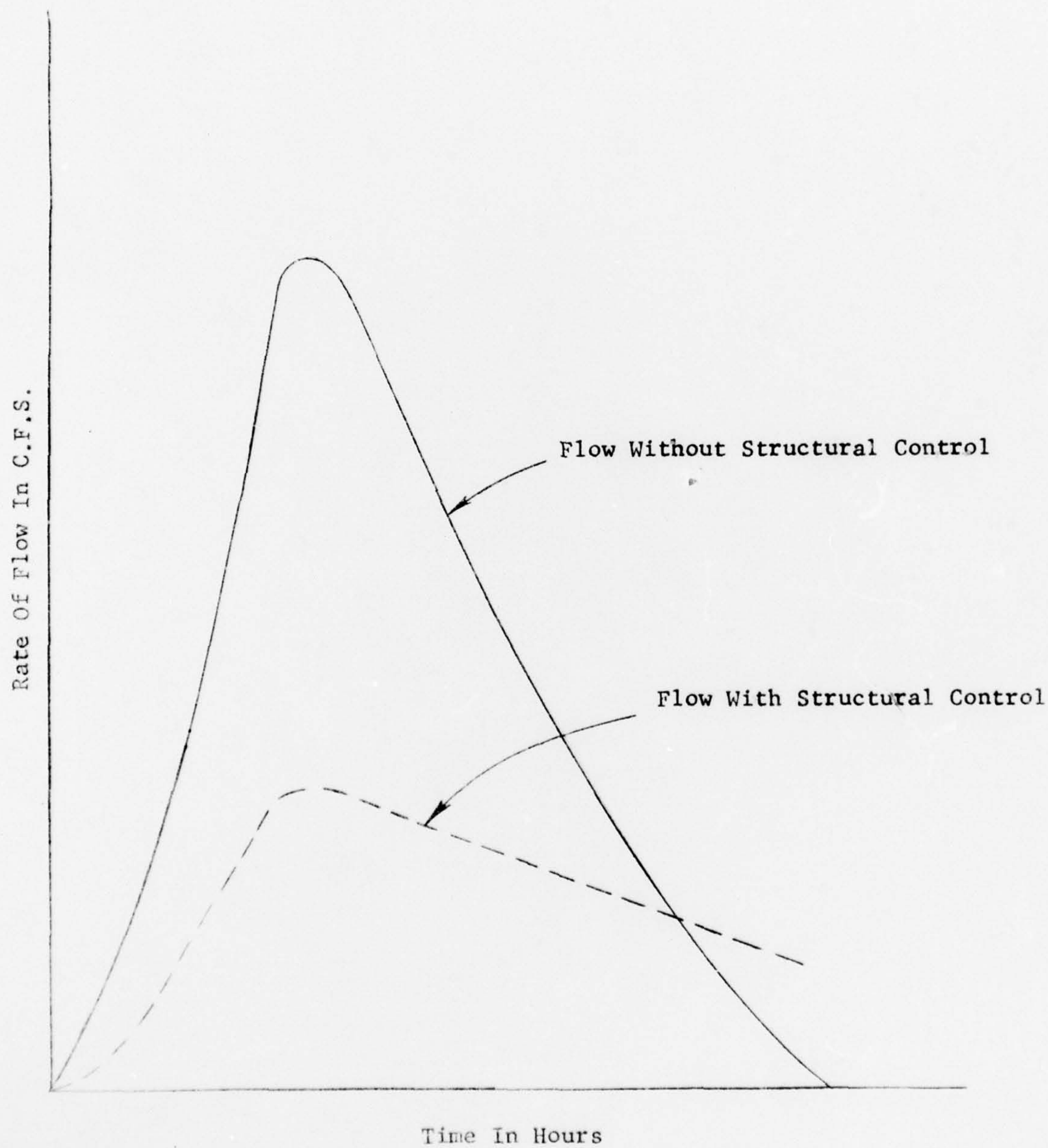

FIGURE 17